3CHAPTER 3

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GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

30 AMDS/SGPB - 30th Medical Group, Bioenvironmental Engineering, including the Radiation Protection Officer

30 CEG - 30th Civil Engineer Group

30 CEG/CEF - 30th Civil Engineer Group, Fire Protection

45 CES - 45th Civil Engineer Squadron

45 CES/CEF - 45th Civil Engineer Squadron, Fire Protection

45 MDG/SGPB - 45th Medical Group, Bioenvironmental Engineering

45 MDG - 45th Medical Group

45 MDG/SGPH - 45th Medical Group, Radiation Protection

45 and 30 SW/SE - 45th and 30 Space Wing, Office of the Chief of Safety

45 and 30 SW/SES - 45th and 30 Space Wing, Systems Safety

A-50 - Aerozine 50, a 50-50 blend of hydrazine and unsymmetrical dimethyl hydrazine

"A" Basis Allowables - the minimum mechanical strength values guaranteed by the material producers or suppliers such that at least 99 percent of the material they produce or supply will meet or exceed the specified values with a 95 percent confidence level

AC - alternating current

acceptance tests - the required formal tests conducted on flight hardware to ascertain that the materials, manufacturing processes, and workmanship meet specifications and that the hardware is acceptable for intended usage

ACO - Aeronautical Control Officer

AF - Air Force

AFB - Air Force Base

AFI - Air Force Instruction

AFM - Air Force Manual

AFMC - Air Force Material Command

AFML - Air Force Material Lab

AFOSH - Air Force Occupational Safety and Health

AFR - Air Force Regulation

AFSC - Air Force Systems Command, now Air Force Material Command

AFSPC - Air Force Space Command

AFTO - Air Force Technical Order; *see also T.O.*

AGE - aerospace ground equipment

AISC - American Institute of Steel Construction

all-fire level - the minimum direct current or radio frequency energy that causes initiation of an electroexplosive initiator with a reliability of 0.999 at a confidence level of 95 percent as determined by a Bruceton test. Recommended operating level is all-fire current, as determined by test, at ambient temperature plus 150 percent of the minimum all-fire current

allowable load (stress) **-** the maximum load (stress) that can be allowed in a material for a given operating environment to prevent rupture or collapse or detrimental deformation; allowable load (stress) in these cases are ultimate load (stress), buckling load (stress), or yield load (stress), respectively

ANSI - American National Standards Institute

applied load (stress) - the actual load (stress) imposed on the structure in the service environment

ARAR - Accident Risk Assessment Report

Arm/Disarm device - an electrically or mechanically actuated switch that can make or break one or more electroexplosive firing circuits; operate in a manner similar to Safe and Arm devices except they do not physically interrupt the explosive train

arming plug - a removable device that provides electrical continuity when inserted in a firing circuit

ASCE - American Society of Civil Engineers

ASME - American Society of Mechanical Engineers

ASTM - American Society for Testing Materials

ATC - Applied Technology Council

AVE - Airborne Vehicle Equipment

GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

AWS - American Welding Society

"B" Basis Allowables - the mechanical strength values specified by material producers and suppliers such that at least 90 percent of the materials they produce or supply will meet or exceed the specified values with a 95 percent confidence level

BBL - burst before leak

BRCC - Blue Ribbon Crane Committee (Western Range)

brittle fracture - (1) a type of failure mode in structural materials that usually occurs without prior plastic deformation and at extremely high speed, (2) a type of failure mode such that burst of the vessel is possible during cycling [normally this mode of failure is a concern when cycling to the maximum expected operating pressure (MEOP) or when the vessel is under sustained load at MEOP], and (3) a type of fracture that is characterized by a flat fracture surface with little or no shear lips (slant fracture surface) and at average stress levels below those of general yielding

Bruceton test method - a statistical method for determining the all-fire and no-fire characteristics of an electroexplosive device using a small sample size, but with high reliability

burst factor - a multiplying factor applied to the MEOP to obtain the design burst pressure. Synonymous with *ultimate pressure factor*

CAD - computer-aided design

CAL-OSHA - California Occupational Safety and Health Act

Category A EED/Ordnance - electroexplosive devices or ordnance that, by the expenditure of their own energy or because they initiate a chain of events, may cause serious injury or death to personnel or damage to property

Category B EED/Ordnance - electroexplosive devices or ordnance that, by the expenditure of their own energy or because they initiate a chain of events, will not cause serious injury or death to personnel or damage to property

cc - cubic centimeter

CCAS - Cape Canaveral Air Station

CCB - Configuration Control Board

cDR - Conceptual Design Review

CDR - Critical Design Review

certified inspector - a person qualified and certified in nondestructive examination inspection techniques according to the American Society for Nondestructive Testing, recommended practices (SNT-TC-1A)

CFR - Code of Federal Regulations

CGA - Compressed Gas Association

CMAA - Crane Manufacturers Association of America

compatibility - the ability of two or more materials or substances to come in contact without altering their structure or causing an unwanted reaction in terms such as permeability, flammability, ignition, combustion, functional or material degradation, contamination, toxicity, pressure, temperature, shock, oxidation, or corrosion

composite material - the combinations of materials differing in composition or form on a macroscale. The constituents retain their identities in the composite. Normally, the constituents can be physically identified, and there is an interface between them

COPV - Composite Overwrap Pressure Vessel

COTS - in reference to software, commercial off the shelf

CPIA - Chemical Propulsion Information Agency

cps - cycles per second

CPU - Central Processing Unit

CRCs - Cyclic Redundancy Checks

critical hardware - any hazardous or safety critical equipment or system; non-hazardous DoD high value items such as spacecraft, missiles, or any unique item identified by DoD as critical; non-hazardous, high value hardware owned by Range Users other than the DoD may be identified as critical or non-critical by the Range User

critical condition - the most severe environmental condition in terms of loads, pressures, and temperatures, or combination thereof imposed on

GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

structures, systems, subsystems, and components during service life

critical flaw - a specific shape of flaw with sufficient size that unstable growth will occur under the specific operating load and environment

critical load - a load consisting of critical hardware and/or any personnel

critical stress intensity factor - the stress intensity factor at which an unstable fracture occurs

cryogen - a super cold liquid such as liquid nitrogen or oxygen

CW - continuous wave

damage tolerance - a measure of the ability of structures to retain load carrying capability after exposure to sudden loads (for example, ballistic impact).

dB - decibel; a unit of relative power; the decibel ratio between two power levels, P1 and P2, is defined by the relation dB = 10log (P1/P2)

dBA - decibels referenced to the “A” scale

DC - direct current

DDESB - Department of Defense Explosive Safety Board

dedicated - serving a single function, such as a power source serving a single load

design burst pressure - the calculated pressure (the analytical value that was calculated using an acceptable industry and/or government practice to determine its design pressure) that components must withstand without rupture and/or burst to demonstrate its design adequacy in a qualification test. During qualification testing, the actual burst pressure for a tested component must demonstrate that the design burst pressure is less than the actual burst pressure. Safety factors are based on design burst pressure, not actual burst pressure of a particular component.

design safety factor - a factor used to account for uncertainties in material properties and analysis procedures; often called *design factor of safety* or simply *safety factor*

destabilizing pressure - a pressure that produces comprehensive stresses in a pressurized structure or pressure component

detent - a releasable element used to restrain a part before or after its motion; detents are common arming mechanisms. Safe and Arm device safing pins use a spring-loaded detent to secure the pin in the device.

detonating cord - a flexible fabric tube containing a filler of high explosive material intended to be initiated by an electroexplosive device; often used in destruct and separation functions

detonation - an exothermic chemical reaction that propagates with such rapidity that the rate of advance of the reaction zone into the unreacted material exceeds the velocity of sound. The rate of advance of the reaction zone is termed *detonation velocity*. When this rate of advance attains such a value that it will continue without diminution through the unreacted material, it is termed the *stable detonation velocity*. When the detonation velocity is equal to or greater than the stable detonation velocity of the explosive, the reaction is termed a *high-order detonation*; when it is lower, the reaction is termed a *low-order detonation.*

detonator - an explosive device (usually an electroexplosive device) that is the first device in an explosive train and is designed to transform an input (usually electrical) into an explosive reaction

detrimental deformation - includes all structural deformations, deflections, or displacements that prevent any portion of the structure from performing its intended function or that reduces the probability of successful completion of the mission

development test - a test to provide design information that may be used to check the validity of analytic technique and assumed design parameters, to uncover unexpected system response characteristics, to evaluate design changes, to determine interface compatibility, to prove qualification and acceptance procedures and techniques, or to establish accept and reject criteria

deviation - a term used when a noncompliance is known to exist prior to hardware production or an operational noncompliance is known to exist prior to operations at CCAS or Vandenberg Air Force

GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

Base

DH - Design Handbook from AFSC

DoD - Department of Defense

DOT - Department of Transportation

ductile fracture - a type of failure mode in structural materials generally preceded by large amounts of plastic deformation and in which the fracture surface is inclined to the direction of the applied stress

dudding - the process of permanently degrading an electroexplosive initiator to a state where it cannot perform its designed function

EBW - high voltage exploding bridgewire initiator; an initiator in which the bridgewire is designed to be exploded (disintegrated) by a high energy electrical discharge that causes the explosive charge to be initiated

EBW-FU - high voltage exploding bridgewire firing unit

EED - low voltage electroexplosive device

EEPROM - Electrically Erasable Programmable Read-Only Memory

EFP - explosively formed projectile

EGSE - electrical ground support equipment

electrical component - a component such as a switch, fuse, resistor, wire, capacitor, or diode in an electrical system

EMC - electromagnetic compatibility

e-N - (Low Cycle Fatigue) strain-life fatigue curve, normally plotted in terms of cyclic strain amplitude versus the number of cycles to failure

EPA - Environmental Protection Agency

EPC - emergency power cutoff

ER - Eastern Range

ESD - electrostatic discharge

ESMC - Eastern Space & Missile Center (Now 45 SW)

ETA - explosive transfer assembly; explosive train; an arrangement of explosive or combustible elements used to perform or transfer energy to an end function

ETS - explosive transfer system

explosion proof apparatus - an enclosure that will withstand an internal explosion of gases or vapors and prevent those gases or vapors from igniting the flammable atmosphere surrounding the enclosure, and whose external temperature will not ignite the surrounding flammable atmosphere

explosives - all ammunition, demolition material, solid rocket motors, liquid propellants, pyrotechnics, and ordnance as defined in AFMAN 91-201 and DoD-STD 6055.9

explosives quantity distance site plan - a formal plan for explosives facilities and areas required per AFMAN 91-201 and DoD 6055.9-STD detailing explosives quantity operating and storage limits and restrictions, and resultant distance clearance requirements

factor of safety (ultimate) **-** the ratio of the ultimate stress to the maximum calculated stress based on limit loads; Ultimate Factor of Safety = Ultimate Strength/Limit Load Stress

factor of safety (yield) **-** the ratio of the yield stress to the maximum calculated stress based on limit loads. Yield Factor of Safety = Yield Strength/Limit Load Stress

fail safe - a design feature in which a system reacts to a failure by switching to or maintaining a safe operating mode that may include system shut down

failure - the inability of a component or system to perform its designed function within specified limits

fatigue - the progressive localized permanent structural change that occurs in a material subjected to constant or variable amplitude loads at stresses having a maximum value less than the ultimate strength of the material

fatigue life - the number of cycles of stress or strain of a specified character that a given material sustains before failure of a specified nature occurs

fault - a manifestation of an error in software

fault tolerance - the built-in ability of a system to

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provide continued correct operation in the presence of a specified number of faults or failures

FCDC - flexible confined detonating cord

FED-STD - Federal Standard

FEMA - Federal Emergency Management Association

firing circuit - the current path between the power source and the initiating device

firmware - computer programs and data loaded in a class of memory that cannot be dynamically modified by the computer during processing. For Systems Safety purposes, firmware is to be treated as software.

fittings - pressure components of a pressurized system initialized to connect lines, other pressure components, and/or pressure vessels within the system

flaw - an imperfection or unintentional discontinuity that is detectable by nondestructive examination

FLSC - flexible linear shaped charge

FM - frequency modulation; Factory Mutual Corporation

FMECA - Failure Mode Effects and Criticality Analysis

FOC - fiber optic cable

FOCA - fiber optical cable assembly

fracture control - the application of design philosophy, analysis method, manufacturing technology, quality assurance, and operating procedures to prevent premature structural failure due to the propagation of cracks or crack-like flaws during fabrication, testing, transportation and handling, and service

fracture mechanics - an engineering concept used to predict flaw growth of materials and structures containing cracks or crack-like flaws; an essential part of a fracture control plan to prevent structure failure due to flaw propagation

fracture toughness - a generic term for measures of resistance to extension of a crack

ft - foot, feet

FTS - Flight Termination System

FU - firing unit

fuse - a system used to initiate an explosive train

G - gravity

GH_2 - Gaseous Hydrogen

GHe - Gaseous Helium

GHz - Gigahertz

GN2 - Gaseous Nitrogen

GOX - Gaseous Oxygen

gr/ep - graphite epoxy

GSE - ground support equipment

h - hour, hours

handling structures - structures such as beams, plates, channels, angles, and rods assembled with bolts, pins, and/or welds; includes lifting, supporting and manipulating equipment such as lifting beams, support stands, spin tables, rotating devices, and fixed and portable launch support frames

hardware (computer) - physical equipment used in processing

hazard- equipment, system, operation, or condition with an existing or potential condition that may result in a mishap

hazard analysis - the analysis of systems to determine potential hazards and recommended actions to eliminate or control the hazards

hazard proof - a method of making electrical equipment safe for use in hazardous locations; these methods include explosion proofing, intrinsically safe, purged, pressurized, and nonincendive and must be rated for the degree of hazard present

hazardous LBB - a pressure vessel that exhibits a leak before burst failure mode and contains a hazardous material

hazardous materials - liquids, gases, or solids that may be toxic, reactive, or flammable or that may cause oxygen deficiency either by themselves or in combination with other materials

hazardous pressure systems - systems used to store and transfer hazardous fluids such as cryo-

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gens, flammables, combustibles, hypergols; systems with operating pressures that exceed 250 psig; systems with stored energy levels exceeding 14,240 ft lb; systems that are identified by Range Safety as safety critical; *see also safety critical*

HDBK - handbook

Hg - mercury

HMX - cyclotetramethylmetetranitramine

HNS - 2,2,4,4,6,6 hexanitrostilbene

hoist angle - an angle at which the load line is pulled during hoisting

holdfire - an interruption of the ignition circuit of a launch vehicle

hot flow - a flow of live commodity in a newly assembled system to normally passivate system walls and components and to remove residual nonactive contaminants or flushing fluid. The hot flow is not intended for leak checks because of the potential hazards due to leaks.

HVDS - hypergolic vapor detection system

Hydraset - the trade name for a closed circuit hydraulically operated instrument installed between a crane hook and load that allows precise control of lifting operations and provides an indication of applied load; precision load positioning device

hydraulic - operated by water or any other liquid under pressure; includes all hazardous fluids as well as typical hydraulic fluids that are normally petroleum-based

hydrogen embrittlement - a mechanical-environmental failure process that results from the initial presence or absorption of excessive amounts of hydrogen in metals, usually in combination with residual or applied tensile stresses

hygroscopic - absorbs moisture from the air

hypergolic - ignites spontaneously upon contact, such as certain rocket fuels and oxidizers

Hz - hertz

IEEE - Institute of Electrical and Electronic Engineers

igniter - a device containing a specifically arranged charge of ready burning composition, usually black powder, used to amplify the initiation of a primer

in.- inch, inches

independent - not capable of being influenced by other systems

indication - the response or evidence from the application of a nondestructive examination including visual inspection

inhibit - an independent and verifiable mechanical and/or electrical device that prevents a hazardous event from occurring; device has direct control and is not the monitor of such a device

initial crack size - a crack dimension determined by nondestructive examination methods or proof test logic

initial flaw - a flaw in a structural material before the application of load and/or environment

initiator - includes low voltage electroexplosive devices and high voltage exploding bridgewire devices

interrupter - a mechanical barrier in a fuse that prevents transmission of an explosive effect to some elements beyond the interrupter

intrinsically safe - incapable of producing sufficient energy to ignite an explosive atmosphere and two-fault tolerant against failure with single fault tolerance at 1.5 times the maximum voltage or energy

ionizing radiation - gamma and X-rays, alpha and beta particles and neutrons

ISI - In-Service Inspection

INSRP - Interagency Nuclear Safety Review Panel

JP - jet propellant

KIc - critical stress intensity factor under Mode 1 conditions (opening mode)

KIe - surface-crack tension specimen fracture toughness; it is a nominal fracture toughness value based on residual strength and original crack dimensions

Kc - critical stress intensity factor under Mode 1 (for example, opening mode) conditions

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KHB - Kennedy Handbook

KHz - kilohertz

KISCC - stress-corrosion, cracking threshold; a level of sustained loading as defined by linear elastic fracture mechanics, below which stress-corrosion cracking does not occur in a specified combination of material and environment

KMAX - maximum stress intensity factor

KSC - Kennedy Space Center

kV - kilovolts

launch vehicle - a vehicle that carries and/or delivers a payload to a desired location; this is the generic term that applies to all vehicles that may be launched from the Ranges; includes, but is not limited to, airplanes, all types of space launch vehicles, manned launch vehicles, missiles and rockets and their stages, probes, aerostats and balloons, drones, remotely piloted vehicles, projectiles, torpedoes, and air-dropped bodies

lb - pound, pounds

LBB - leak before burst; a failure mode in which it can be shown that any initial flaw will grow through the wall of a pressure vessel or pressurized structure and cause leakage rather than brittle fracture/burst before leak; normally determined at or below maximum expected operating pressure

lead angle - an angle in which the load line is pulled during hoisting. Commonly used to refer to an angle in line with the grooves in the drum or sheaves

LEL - lower explosive limit

LFU - laser firing unit

LH_2 - liquid hydrogen

LHe - liquid helium

LID - laser initiated device

limit load (design load) **-** the maximum load or combination of loads a part or structure is expected to experience at any time during its intended operation and expected environment; limit load = (load factor) x (rated load)

lines - tubular pressure components of a pressurized system provided as a means for transferring fluids between components of the system

LIO - laser initiated ordnance

LIOS - laser initiated ordnance system

LN_2 - liquid nitrogen

load factor - a factor that accounts for unavoidable deviations of the actual load from the nominal value. Examples of load factors include wind, shock, seismic, and dynamic load factors

loading spectrum - a representation of the cumulation loadings anticipated for the structure under all expected operating environments; significant transportation and handling loads are included

LOCC - Launch Operations Control Center

LOX - liquid oxygen (also LO_2)

LSC - Linear Shaped Charge

LV - launch vehicle

mA - milliamperes

MA - managing activity

MAC - maximum allowable concentration

major mishap - an event or incident that has the potential of resulting in a fatality or major damage such as the loss of a processing facility, launch complex, launch vehicle, or payload

margin of safety - the percentage by which the allowable load (stress) exceeds the limit load (stress) for specific design conditions; Yield Margin of Safety = [(Yield Strength/Limit Load Stress) x (Yield Factor of Safety)] - 1; Ultimate Margin of Safety = [(Ultimate Strength/Limit Load Strength) x (Ultimate Factor of Safety)] - 1

MAWP - maximum allowable working pressure

MDC - mild detonating cord

MDF - mild detonating fuse

meets intent certification - a certification used to indicate an equivalent level of safety is maintained despite not meeting the exact requirements stated in the document

megger - high voltage resistance meter

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MEOP - maximum expected operating pressure; the highest pressure that a pressure vessel, pressurized structure, or pressure component is expected to experience during its service life and retain its functionality, in association with its applicable operating environments; synonymous with maximum operating pressure (MOP) or maximum design pressure (MDP); includes the effect of temperature, pressure transients and os-cillations, vehicle quasi-steady, and dynamic accelerations and relief valve operating variability

MFCO - Mission Flight Control Officer

MHE - material handling equipment used to handle lift, support, or manipulate critical or non-critical hardware. MHE includes, but is not limited to, cranes, hoists, sling assemblies, hydrasets and load cells, handling structures, and personnel work platforms.

MHI - Materials Handling Institute

MHz - megahertz

MIC - meets intent certification

MIL - military

MIL-HDBK - Military Handbook

MIL-Spec - Military Specification

MIL-STD - Military Standard

min - minute, minutes

mismating - the improper installation and/or connection of connectors

MMH - monomethylhydrazine

monitor circuit - a circuit used to verify the status of a system, such as an inhibit directly; control circuits can be monitored but they can not serve as a monitor circuit

MOP - maximum operating pressure; the maximum operating pressure a system will be subjected to during planned static and dynamic conditions

MSDS - Material Safety Data Sheet

MSFC - Marshal Space Flight Center

MSPSP - Missile System Prelaunch Safety Package; a data package that demonstrates compliance with Chapter 3 of this document and serves as a baseline for safety-related information for a system throughout its life cycle

N_2H_4 - Hydrazine

N_2O_4 - Nitrogen Tetroxide

NACE - National Association of Corrosion Engineers

NASA - National Aeronautical and Space Administration

NASC - National Aeronautics and Space Council

NDE - non-destructive examination; any testing, inspection, or evaluation that does not cause harm to or impair the usefulness of an object satisfies the meaning of the word *non-destructive*. In common usage, *testing* (NDT) often refers just to test methods and test equipment with only a general reference to materials and/or parts. *Inspection* (NDI) relates to specific written requirements, procedures, personnel, standards, and controls for the testing of a particular material of a specific part. *Evaluation* is concerned with the decision making process, the determination of the meanings of the results, of the final acceptance or rejection of the material of part, and may be qualitative or quantitative.

NEC - National Electrical Code

NEI - nonexplosive initiators

NFPA - National Fire Protection Association

NIOSH - National Institute of Occupational Safety and Health

no-fire level - the maximum direct current or RF energy at which an electroexplosive initiator shall not fire with a reliability of 0.999 at a confidence level of 95 percent as determined by a Bruceton test and shall be capable of subsequent firing within the requirements of performance specifications

noise margin - the margin between the worst case noise level and logic circuitry threshold

noncritical hardware - equipment and systems employed for standard industry use; equipment and systems that are determined not to be hazardous, safety critical, or of high value

non-incendive - will not ignite group of gases or vapors for which it is rated; similar to *intrinsically*

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safe, but does not include failure tolerance ratings; used in rating electrical products for Class I, Division 2 locations only

NPT - National Pipe Thread

NRC - Nuclear Regulatory Commission

NSC - National Security Council

OIS - operational intercommunication system; operational information system

operating life - the period of time in which prime power is applied to electrical or electronic components without maintenance or rework

ordnance - all ammunition, demolition material, solid rocket motors, liquid propellants, pyrotechnics, and explosives as defined in AFMAN 91-201 and DoD 6055.9-STD

ordnance component - a component such as a squib, LOS, detonator, initiator, ignitor, or linear shape charge in an ordnance system

OSC - Operations Safety Console

OSHA - Occupational Safety and Health Act

O&SHA - Operating and Support Hazard Analysis

OSTP - Office of Science Technology Policy

PA - Public Address

PAD - percussion activated device

passive device - a device that permits signals to transient through it without modifying the signals

payload - the object(s) within a payload fairing carried or delivered by a launch vehicle to a desired location. This is a generic term that applies to all payloads that may be delivered from the ER or WR and includes, but is not limited to, satellites, other spacecraft, experimental packages, bomb loads, warheads, reentry vehicles, dummy loads, cargo, and any motors attached to them in the payload fairing

PD - Presidential Directive

PDR - Preliminary Design Review

personnel work platforms - platforms used to provide personnel access to flight hardware at off-pad processing facilities as well as at the launch pad; they may be removable, extendible, or hinged.

PETN - pentaerythritoltetranitrate

PHE - Propellant Handler's Ensemble

PL - Public Law

PLC - programmable logic controller

pneumatic - operated by air or other gases under pressure

POL - paints, oils, lubricants

PPE - personal protective equipment

ppm - parts per million

pressure component - a component such as lines, fittings, valves, regulators, and transducers in a pressurized system. Normally pressure vessels or pressurized structures are excluded, because of the potential energy contained, they generally require additional analysis, test and inspection.

pressure system - any system above 0 psig that is classified as follows: low pressure, 0 to 500 psi; medium pressure, 501 to 3000 psi; high pressure, 3001 to 10,000 psi; ultra-high pressure, above 10,000 psi. **NOTE**: The degree of hazard of a pressure system is proportional to the amount of energy stored, not the amount of pressure it contains; therefore, low pressure, high volume systems can be as hazardous to personnel as high pressure systems.

pressure vessel - a container that stores pressurized fluids and (1) contains stored energy of 14,240 foot pounds (19,130 joules) or greater based on adiabatic expansion of a perfect gas; or (2) contains gas or liquid which will create a mishap (accident) if released; or (3) will experience a MEOP greater than 100 psia. Excluded are special equipment including batteries, cryostats (or dewars), heat pipes, and sealed containers; or (4) per the ASME definition, summarized briefly; pressure containers that are integral pumps or com-pressors, hot water heaters and boilers, vessels pressurized in excess of 15 psi (regardless of size), and vessels with a cross-sectional dimension greater than 6 in. (regardless of length of the vessel or pressure).

pressurized system - a system that consists of pressure vessels or pressurized structures, or both,

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and other pressure components such as lines, fittings, valves, and bellows that are exposed to and structurally designed largely by the acting pressure; electrical or other control devices required for system operation are not included; a pressurized system is often called a *pressure system*

pressurized structure - a structure designed to carry both internal pressure and vehicle structural loads; the main propellant tank of a launch vehicle is a typical example

primacord - a detonating fuse used in destruct or separation functions

program - the coordinated group of tasks associated with the concept, design, manufacture, preparation, checkout and launch of a launch vehicle and/or payload to or from, or otherwise supported by the Eastern or Western Ranges and the associated ground support equipment and facilities

proof factor - a multiplying factor applied to the limit load or MEOP to obtain proof load or proof pressure for use in the acceptance testing

proof pressure - (1) the product of MEOP and a proof factor accounting for the difference in material properties between test and service environment (such as temperature); used to give evidence of satisfactory workmanship and material quality; for example, demonstrating that the component and/or system will not deform, leak or fail; (2) may be used to establish maximum initial flaw sizes for safe-life demonstration.

propellant storage tank - any container of propellants greater than one gallon. application of requirements of this document shall normally vary with the size of the tank and associated hazards. Containers less than one gallon shall also be subject to operational controls as a container of flammable liquid

psig - pounds per square inch gauge

PTFE - Polytetraflouroethylene

QD - quick disconnect

qualification tests - the required tests used to demonstrate that the design, manufacturing, and assembly have resulted in hardware conforming to specification requirements

radiation source - materials, equipment, or devices that generate or are capable of generating ionizing radiation including naturally occurring radioactive materials, by-product, source materials, special nuclear materials, fission products, materials containing induced or deposited radioactivity, nuclear reactors, radiographic and fluoroscopic equipment, particle generators and accelerators, radio frequency generators such as certain klystrons and magnetrons that produce X-rays, and high voltage devices that produce X-rays

radioactive material - materials that generate, or are capable of generating, ionizing radiation including naturally occurring radioactive materials, by-product materials, source materials, special nuclear materials, fission products, materials containing induced or deposited radioactivity, and nuclear reactors

radioactive equipment or device - equipment or devices that generate, or are capable of generating, ionizing radiation including radiographic and fluoroscopic equipment, particle generators and accelerators, radio frequency generators such as certain klystrons and magnetrons that produce X-rays, and high voltage devices that produce X-rays

RADSAFCOM - Radiation Safety Committee, Western Range

RAM - random access memory

Range Users - clients of CCAS and VAFB such as Department of Defense, non-Department of Defense government agencies, civilian commercial companies, and foreign government agencies that use Range facilities and test equipment, conduct prelaunch, launch, and impact operations, or require on-orbit support

GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

rated load - the maximum static load or force that can be imposed on the part or structure at any time during its intended operation and expected environment

RCO - Range Control Officer

RDX - cyclotrimethylenetrinitramine

Recertification File - a file that contains data showing that a specific piece of MHE/MGSE meets the periodic test and inspection requirements of this document

redundant - a situation in which two or more independent means exist to perform a function

referee fluid - a compatible fluid, other than that used during normal system operations, that is used for test purposes because it is safer due to characteristics such as less (or non-) explosive, flammable, or toxic and/or easier to detect

remote control - control of a system from a remote and safe location

residual strength - the maximum value of nominal stress, neglecting the area of the crack, that a cracked body is capable of sustaining

residual stress - the stress that remains in a structure after processing, fabrication, assembly, testing, or operation; for example, welding induced residual stress

RF - radio frequency; electromagnetic energy from 30 kHz to 300 GHz

rms - root mean square

ROM - read only memory

RP - rocket propellant

RPIE - Real Property Installed Equipment

RPO - Radiation Protection Officer; a 45th MDG/SGPH or 30 AMDS/SGPB person responsible for the requirements of 45 SWI 40-201 and AFI 91-110 30 SW1, respectively

RSOR - Range Safety Operations Requirements

RT - Radiographic Testing

RV - reentry vehicle

S & A - safe and arm device; a device that provides mechanical interruption (safe) or alignment (arm) of the explosive train and electrical interruption (safe) or continuity (arm) of the firing circuit

Safe/Arm plug - normally two plugs; the ARM plug is inserted in the firing circuit to provide continuity. The ARM plug is removed and the SAFE plug inserted that shorts the electroexplosive device (EED) leads and provides static bleed capability, although some circuits have this protection inherent in their design. Shorting plugs and connectors that are placed on EED leads after disconnecting the cable are not the same as safing plugs, although they may perform similar functions.

SAE - Society of Automotive Engineers

safety critical - an operation, process, system, or component that controls or monitors equipment, operations, systems, or components to ensure personnel, launch area, and public safety; may be hazardous or non-hazardous

safety critical computer system function - a computer function containing operations that, if not performed, if performed out of sequence, or if performed incorrectly, may result in improper or lack of required control functions that may directly or indirectly cause a hazard to exist

safety factor - the ratio of design burst pressure over the maximum allowable working pressure or design pressure; it can also be expressed as the ratio of tensile or yield strength over the maximum allowable stress of the material

safety kernel - an independent computer program that monitors the state of a system to determine when potentially hazardous system states occur or when transitions to potentially hazardous system states may occur. The safety kernel is designed to prevent the system from entering the hazardous state and return it to a known safe state.

SAS - Safety Analysis Summary

SCAPE - Self-Contained Atmospheric Protective Ensemble

SCBB - Software Configuration Control Board

scc - standard cubic centimeter

GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

SCCSF - Safety Critical Computing System Functions

SDD - Software Design Description; a representation of a software system created to facilitate analysis, planning, implementation, and decision-making; a blueprint or model of the software system; used as the primary medium for communicating software design information

SDP - Software Development Plan

SEAOC - Structural Engineers Association of California

serious mishap - an event or incident that has the potential of resulting in injury to personnel and damage to high value property or that might require the use of contingency or emergency procedures

service life - (1) the total life expectancy of a part or structure; service life starts with the manufacture of the structure and continues through all acceptance testing, handling, storage, transportation, operations, refurbishment, retesting, and retirement; (2) the period of time between the initial lot acceptance testing and the subsequent age surveillance testing for ordnance

SEU - Single Event Upset

SFP - single failure point; in general, a component that, if failed, could lead to the overall failure of the system; for example in a mechanical system, a component such as a lug, link, shackle, pin, bolt, or rivet, or a weld that, if failed, could cause a system inability to support a load using load path analysis

SHA - software hazard analysis

shall - mandatory action

shelf life, battery - the specified period of time a battery may be stored in a logistical environment and still perform to all required specifications when placed in service

shelf life, explosive - the period of time between explosive loading and end use

shield (RF) **-** a metallic barrier that completely encloses a device for the purpose of preventing or reducing induced energy

should - recommended action

single failure point analysis - in general, an analysis to identify single failure points; for mechanical systems, a load path analysis. A stress analysis of the resultant system after the first load path failure (of a single failure point). Twice the resultant dead weight shall be used in the analysis to account for the sudden redistribution of the load and an allowable stress of 90 percent of the ultimate material stress shall be used.

sling - a lifting assembly and associated hardware used between the load and the hoisting device hook

S-N - stress versus cycles; normally plotted in the form of a curve/diagram and is cyclic stress amplitude versus the number of cycles to failure

soft goods - the nonmetal materials in a pressure system that are used to form a seal or seat for metal-to-metal contact or between other hard surfaces

SPEC - specification

SRR - System Requirements Review

SSCF - software safety critical function

SSED - safe skin exposure distance

STP - Software Test Plan

STS - Space Transportation System

stress-corrosion cracking - a mechanical-environmental induced failure process in which sustained tensile stress and chemical attack combine to initiate and propagate a crack or a crack-like flow in a metal part

stress intensity factor - a parameter that characterizes the stress-strain behavior at the tip of a crack contained in a linear elastic, homogeneous, and isotropic body

structural component - a component such as a bolt, lug, hook, shackle, pin, rivet, or weld in a MHE

surface inspection - a nondestructive examination method, other than visual, used for detection of surface and near surface discontinuities

TLV - threshold limit value

TNSE - Technical Nuclear Safety Evaluation

GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

T.O. - Technical Order

TOPS - transistorized operational phone system

UDMH - unsymmetrical dimethyl hydrazine

UL - Underwriter's Laboratories

ultimate load - the product of the limit load and the design ultimate load factor. It is the load that the structure must withstand without rupture or collapse in the expected operating environment

ultimate strength - the stress at which a material exhibits failure (i.e., fracture/break)

UN - United Nations

USAF - United States Air Force

UT - ultrasonic testing

Vac - voltage, alternating current

VAFB - Vandenberg Air Force Base

Vdc - voltage, direct current

VHF - very high frequency

volumetric inspection - a nondestructive testing method to determine the presence of discontinuities throughout the volume of a material

Vrms - voltage, root mean square

waiver - a designation used when, through an error in the manufacturing process or for other reasons, a hardware noncompliance is discovered after hardware production or an operational noncompliance is discovered after operations have begun at CCAS or VAFB

WR - Western Range

WP-S - A classification for a fitting(s) that is manufactured from seamless product by a seamless method of manufacturer (marked with class symbol, WP-S)

WP-WX - A classification for a fitting(s) that contains welds where all welds have been radiographed (marked with class symbol, WP-WX)

yield strength - the stress at which a material exhibits a specified permanent deformation or set

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29 CFR 1910.119, OSHA *Process Safety Management of Highly Hazardous Chemicals*

29 CFR 1910.184, *OSHA Slings*

29 CFR 1926.550, *OSHA Cranes & Derricks*

30 SW1, *Radiation Protection Plan*

40 CFR 264.193, *Containment & Detection of Releases*

40 CFR 280, *Technical Standards & Corrective Action Requirements for Owners & Operators of Underground Storage Tanks*

45 SWI 40-201, *Radiation Protection Program*

49 CFR 170-179, *DOT*

Aerospace Structural Metals Handbook

AFI 32-104, *Standard Facility Requirements*

AFI 32-2001, *The Fire Protection Operations and Fire Prevention Program*

AFI 32-3001, *Explosive Ordnance Disposal Program*

AFI 32-4002, *Hazardous Material Emergency Planning and Response Compliance*

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AFOSH 161-9, *Exposure to Radio Frequency Radiation*

AFOSH 161-10, *Health Hazards For Radiation*

AFOSH 161-20, *Hearing Conservation Program*

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AFTO, *Air Force Technical Order,* see also T.O. in this document

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ANSI/ASME B30.3, *Hammerhead, Tower Cranes Devices*

ANSI/ASME B30.4, *Portal, Tower, and Pillar Cranes*

ANSI/ASME B30.5, *Mobile and Locomotive Cranes*

ANSI/ASME B30.6, *Derricks*

ANSI/ASME B30.7, *Base Mounted Drum Hoists*

ANSI/ASME B30.8, *Floating Cranes and Floating Derricks*

ANSI/ASME B30.9, *Slings*

ANSI/ASME B30.11, *Monorail Systems and Underslung Cranes*

ANSI/ASME B30.16, *Overhead Hoists*

ANSI/ASME B30.17, *Overhead & Gantry Cranes*

REFERENCED DOCUMENTS

ANSI/ASME B30.20, *Below Hook Lifting Devices*

ANSI/ASME B1.1, *Unified Inch Screw Threads*

ANSI/ASME B16.4, *Gray Iron Threaded Fittings*

ANSI/ASME B16.5, *Pipe Flanges and Flanged Fittings*

ANSI/ASME B16.9, *Factor-Made Wrought Steel Butt Welding fittings*

ANSI/ASME B18.2.1, *Square and Hex Bolts and Screw Inch Series*

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ASTM A 403, *Standard Specifications for Wrought Austentic Stainless Steel Pipe Fittings*

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AWS D1.2, *Structural Welding Code Aluminum*

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AWS D14.2, *Metal Cutting Machine Tool Weldments*

AWS D14.4, *Classification and Application of Welded Joints for Machinery and Equipment*

BRCC, *Design Requirements Handbook for Electrically Powered Top Running Overhead and Underhung Traveling Cranes*

CAL-OSHA, *Chapter 4, General Industry Safety Order*

CAL-OSHA, *Title 8, Administrative Code*

CMAA 70, *Overhead Cranes*

CMAA 74, *Overhead Hoists*

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CPIA 194, *Chemical Rocket/Propellant Hazards*

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KSC-SPEC-Z-0007, *Tubing, Steel Corrosion Resistance Type 304, 316, Seamless Spec 4*

KSC-SPEC-Z-0009, *Lubrication Thread Corrosion Resistance Steel, Aluminum Alloy Tube Fitting*

KSC-STD-0001, *Standard for Protections, Coating of Carbon Steel & Aluminum on Launch Structure Facility & Ground Support Equipment*

KSC-STD-E-0012, *Bonding and Grounding*

Material Handling Institute Standards

MIL-B-5087, *Bonding, Electrical and Lightning Protection for Aerospace Systems*

MIL-E-5400, *General Specifications for Airborne Electronic Equipment (Inactive)*

MIL-E-605l, *Electromagnetic Systems Compatibility Requirements*

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MIL-STD-1316, *Fuse Design Safety, Criteria*

MIL-STD-1472, *Human Engineering Design Criteria for Military Systems, Equipment, and Facilities*

MIL-STD-1540, *Test Requirements for Space Vehicles*

MIL-STD-1543, *Reliability Program Requirements for Space and Launch Vehicles*

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OPLAN 28-74, *Contingency Plan for Incidents Involving Major Radioactive Sources*

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T.O. 00-25-224, *Welding High Pressure and Cryogenic Systems*

T.O. 00-25-229, *Valves and Regulator Criteria for Integrated Pressure Systems (Portable and Installed)*

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T.O. 1-1A-8, *Engineering Manual Series, Aircraft, Missile and Related Aerospace Ground Equipment (AGE) Repair Structural Hardware*

T.O. 11A-1-47, *Explosives Hazard Classification Procedures*

T.O. 14P3-11-1, *Protective Clothing for Handlers of Missile Fuels and Oxidizers*

T.O. 14P3-11-21, *Operations, Service, and Repair Instructions Rocket Fuel Handler's Coveralls, Graylite Jacket, Self-Ventilating Hood*

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CHAPTER 3
LAUNCH VEHICLE, PAYLOAD, AND GROUND SUPPORT EQUIPMENT DOCUMENTATION, DESIGN, AND TEST REQUIREMENTS

3.1 INTRODUCTION

3.1.1 Purpose of the Chapter

Chapter 3 establishes minimum design, test, inspection, and data requirements for hazardous and safety critical launch vehicles, payloads, and ground support equipment, systems, and materials. The following topics are addressed:

3.2 Responsibilities and Authorities
3.3 General Design Policy
3.4 Documentation Requirements
3.5 Operations Safety Console
3.6 Material Handling Equipment
3.7 Acoustic Hazards
3.8 Non-Ionizing Radiation Sources
3.9 Radioactive (Ionizing Radiation) Sources
3.10 Hazardous Materials
3.11 Ground Support Pressure Systems
3.12 Flight Hardware Pressure Systems
3.13 Ordnance Systems
3.14 Electrical and Electronic Equipment
3.15 Motor Vehicles
3.16 Computer Systems and Software
3.17 Seismic Design Criteria (WR only)

3.1.2 Applicability

a. All Range Users operating on the Eastern Range (ER) and Western Range (WR) are subject to the requirements of this Chapter to ensure safety by design, testing, and inspection.

b. The Space Transportation System (STS) *Payload Ground Safety Handbook* (KHB 1700.7) design requirements may be used in lieu of the requirements of this Chapter only for payloads intended to fly on STS. Those systems without design requirements in KHB 1700.7 shall meet the requirements of this Chapter.

3.2 RESPONSIBILITIES AND AUTHORITIES

3.2.1 Systems Safety, 45th and 30th Space Wings

Systems Safety, 45th Space Wing (45 SW/SES) and 30th Space Wing (30 SW/SES) are responsible for the review and approval of the design, inspection, and testing of all hazardous and safety critical launch vehicles, payloads, and ground support equipment, systems, subsystems, and material to be used at Cape Canaveral Air Station (CCAS) and Vandenberg Air Force Base (VAFB) in accordance with the requirements of this Chapter. **NOTE 1:** Unless otherwise noted, all references to *Range Safety* in this Chapter refer to the Systems Safety of the 30th and 45th Space Wings. The responsibilities of Range Safety are as follows:

a. Reviewing and approving all required Missile System Prelaunch Data Packages (MSPSPs)

b. Reviewing and approving all required MSPSP associated Test Plans and Test Reports

3.2.2 Medical Groups, 45th and 30th Space Wings

3.2.2.1 Health Physics

Health Physics, 45th Medical Group (45 MDG/SGPH) and 30th Medical Group (30 AMDS/SGPB) Radiation Protection Officer (RPO) are responsible for reviewing and approving the design, test, and inspection of non-ionizing and ionizing radiation sources in conjunction with Range Safety. **NOTE:** Unless otherwise noted, these agencies will be referred to as the *RPO* in this Chapter.

3.2.2.2 Bioenvironmental Engineering

Bioenvironmental Engineering, 45th Medical Group (45 MDG/SGPH)and 30th Medical Group (30 AMDS/SGPB) are responsible for reviewing and approving the design, test, and inspection of systems with acoustic and radiation hazards. **NOTE:** Unless otherwise noted, these agencies will be referred to as *Bioenvironmental Engineering* in this Chapter.

3.2.3 Civil Engineering, 45th and 30th Space Wings

a. The 45th Civil Engineering Squadron (45 CES) and 30th Civil Engineering Group (30 CEG) Environmental Planning Sections are responsible for reviewing and approving regulated hazardous waste plans and procedures. **NOTE:** Unless otherwise noted, these agencies will be referred to as *Environmental Planning* in this Chapter.

b. The 45th and 30th Fire Marshals (45 CES/CEF) and (30 CEG/CEF) are responsible for establishing hazardous atmosphere classification and other duties. **NOTE:** Unless otherwise noted, these positions will be referred to as *Fire Marshal* in this Chapter.

3.2.4 Range Users

Range Users are responsible for the design, inspection, and testing of all hazardous and safety critical launch vehicle, payload, and ground support equipment, systems, subsystems, and materials to be used at the Ranges in accordance with the requirements of this Chapter. These responsibilities include the following:

a. Timely submission of all required MSPSPs

b. Timely submission of all MSPSP associated Test Plans and Test Reports

3.3 GENERAL DESIGN POLICY

All systems shall be designed to tolerate a minimum number of credible failures. The number of design inhibits required to prevent an overall system failure or mishap is based on the failure or mishap result. Specific inhibit requirements are addressed in the design criteria for each of the systems addressed in this Chapter. Those systems that do not have specific design criteria or systems not addressed in this Chapter shall be designed to the following general criteria:

a. If a system failure may lead to a catastrophic hazard, the system shall have three inhibits (dual fault tolerant).

b. If a system failure may lead to a critical hazard, the system shall have two inhibits (single fault tolerant).

c. If a system failure may lead to a marginal hazard, the system shall have a single inhibit (no fault tolerant).

d. Probabilities of hazard occurrence shall be taken into consideration when determining the number of required inhibits. (See Chapter 1, Table 1-2, “Acceptability Guidelines for Prelaunch Area/Launch Complex Hazard Consequences and Probabilities Categories.”)

e. Systems shall be able to be brought to a safe state with the loss of an inhibit.

f. All inhibits shall be independent and verifiable.

g. Design inhibits shall consist of electrical and mechanical hardware.

h. Operator controls shall not be considered a design inhibit. **NOTE:** Operator controls are considered a control of an inhibit.

3.4 DOCUMENTATION REQUIREMENTS

3.4.1 MSPSP

3.4.1.1 MSPSP Submittal, Review, and Approval Process

a. Range Users shall submit an MSPSP for each new program such as launch vehicle, payload, or stand-alone ground support equipment.

b. Range Safety shall review and provide comments to each of the MSPSP submittals at or prior to the appropriate cDR, PDR, and CDR.

c. A final MSPSP that satisfies all Range Safety concerns addressed at the CDR shall be submitted to Range Safety at least 45 calendar days prior to the intended shipment of hardware to the Ranges.

d. Range Safety shall review the MSPSP and, if the MSPSP is found to be satisfactory, approve it within 10 calendar days of receipt. **NOTE:** The final MSPSP shall be approved prior to shipment of associated hardware to the Ranges.

3.4.1.2 MSPSP Content

a. Guidelines for preparing an MSPSP can be found in Appendix 3A.

b. Specific MSPSP data requirements, including analyses, drawings, plans, specification, and other data are identified in each of the major sections of this Chapter.

3.4.2 MSPSP Associated Test Plans and Test Results

a. All MSPSP associated test plans shall be submitted at least 45 calendar days prior to the intended test plan use.

b. Range Safety shall review and comment on or approve test plans within 45 calendar days of receipt. Disapproved test plans shall be resubmitted. **NOTE:** An approved test plan is required prior to test performance.

c. Test reports shall be submitted within 45 calendar days of intended system use.

d. Range Safety shall review and comment and approve test reports within 10 calendar days of receipt. Disapproved test reports shall be resubmitted. **NOTE:** An approved test report is required prior to system use.

3.5 OPERATIONS SAFETY CONSOLE

3.5.1 Operations Safety Console General Design Requirements

a. Each launch control center, blockhouse, and firing room, as applicable, shall provide for an Operations Safety Console (OSC).

b. An ER/WR OSC shall be provided by the Range User (normally the launch vehicle provider) unless otherwise agreed to by Range Safety. **NOTE:** The ER normally provides an OSC.

c. The Range User shall provide ample and satisfactory space to install and operate the console.

d. No single failure point components shall be in the ground support equipment (GSE) or firing room/launch control center/blockhouse system that will cause the loss of a safety critical system control or monitor (as determined by Range Safety) at the OSC.

e. MIL-STD-1472 should be used as guidance in designing the OSC.

3.5.2 ER OSC Controls, Monitors, and Communication Lines

The OSC shall be in a dedicated position to provide the Operations Safety Manager sufficient information and communications capability to convey safety status and conditions to the appropriate authority (the launch complex control authority for day-to-day operations and the MFCO during a launch operation). At a minimum, the controls, monitors, and communication lines listed below are required at the launch complex OSC. These items are general in nature and may vary depending on the launch vehicle configuration. The monitor circuit shall be designed so that the actual status of the critical parameters can be monitored rather than the command transmittal. **NOTE**: It is important that this console does not have any Flight Termination System (FTS) command transmittal functions.

a. FTS status (Refer to Chapter 4 for requirements)

b. Ignition SAFE and ARM status for all solid rocket motor safe and arm devices

c. An ENABLE control switch and status for all solid rocket motor arming devices

d. Launch vehicle liquid propulsion system inhibits and propellant tank pressure status (psig)

e. Water System (pump station)

1. 18 in. main pressure status

2. 36 in. main pressure status

3. Status for each main pump on-line or off-line

f. Master Communications Control Panel

1. Two administrative telephones with HOLD function

2. Audio-selector push buttons for intercom net and green phones (direct line)

3. Green phones with a minimum of 30 channels

4. Intercom capability via the Operational Information System (OIS) or Transistorized Operational Phone System (TOPS) in which four channels can be accessed simultaneously

5. Paging capabilities

6. Very High Frequency/Frequency Modulation (VHF/FM) radio phone

7. Particular communication requirements will be specified in applicable Range Safety Operations Requirements (RSORs) in accordance with Chapter 7 of this document.

g. Master Countdown status

h. HOLDFIRE (stop launch sequencer) control switch and status active through T-0

i. Ignition firing line ENABLE and DISABLE control switch and status

j. Mission Flight Control Officer (MFCO), Range Control Officer (RCO), and Range User HOLD-FIRE status

k. Emergency Panel

1. Launch complex warning beacon and horn control switch and status

2. Emergency and normal electrical power status for critical locations such as the firing room and launch complex

3.5.3 WR OSC Controls, Monitors, and Communication Lines

The OSC shall be in a dedicated position to provide the Operations Safety Manager sufficient information and communications capability to convey safety status and conditions to the appropriate auth-ority (the launch complex control authority for day-to-day operations and the MFCO during a launch operation). At a minimum, the controls, monitors, and communication needs listed below are required at the launch complex OSC. These items are gen-eral in nature and may vary depending on the launch vehicle configuration. The monitor circuit shall be designed so that the actual status of the critical parameters can be monitored rather than the command transmittal. **NOTE**: It is important that this console does not have any Flight Termination System (FTS) command transmittal functions.

a. FTS SAFE and ARM status for all FTS safe and arm devices

b. Ignition SAFE and ARM status for all solid rocket motor safe and arm devices

c. Launch vehicle liquid propulsion system inhibits and propellant tank pressure status (psig)

d. Communications

1. Countdown net capable of monitoring and transmitting (redundant)

2. Direct line to MFCO

3. Direct line to RCO

4. Direct line to Building 7000 Launch Operations Control Center (LOCC)

5. Direct lines to Test Conductor and Launch Control Officer

6. Direct line to primary access control point for safety control areas

7. Direct line to facility safety net

8. Direct line to Launch Support Team Chief and fallback area

9. Access to facility Public Address (PA) system with emergency override capability

10. At least one Class A dial line

11. Radio Frequency (RF) nets, as required

12. Direct line to Launch Director

13. Direct line to ACO

e. MFCO and Range User HOLDFIRE status

f. Wind speed and direction readouts

g. Complex and Range Clearance Status and Alert (S&A) lights to MFCO *h*. Launch complex warning lights and klaxon/ horn switch and status indicators

3.5.4 OSC Color Television System

a. An OSC color television system shall be provided to ensure the coverage necessary to view all hazardous operations in the launch complex.

b. Control of the television system shall be available at the OSC.

3.5.5 OSC Communication and Video Recording

a. The OSC shall be capable of recording and playback of hazardous operations.

b. Communication and video recording requirements shall be coordinated with the launch controller and test conductor prior to the start of an operation.

c. Designated recordings shall remain on file for 180 days.

3.5.6 OSC Validation and Test Requirements

a. At a minimum, an OSC validation and checkout test shall be performed to demonstrate the following:

1. The correct and reliable operation of OSC functions

2. The validity of OSC outside interfaces

3. The operating limits of the OSC

b. Test Plans, procedures, and results shall be reviewed and approved by Range Safety.

3.5.7 OSC Data Requirements

The following OSC data shall be submitted in the MSPSP:

a. An overall schematic of the OSC and outside interfaces

b. A narrative of each of the features of the OSC, including the following:

1. Function

2. Operation

3. Outside interface

4. Operating limits

c. Test Plan and Maps

3.6 MATERIAL HANDLING EQUIPMENT

This section provides design, initial and periodic test, and initial and recurring data requirements for material handling equipment (MHE) used at the Ranges for handling (lifting, supporting, or manipulating) critical and non-critical hardware. These requirements are applicable for new or modified MHE. The requirements are also applicable for permanent or short-term use MHE and apply whether the equipment is owned, rented, or leased by either government, contractor, or commercial operators.

3.6.1 MHE General Requirements

a. As part of the MSPSP, a list of all MHE equip-ment to be used on the Ranges shall be submitted to Range Safety for review and approval as soon as possible, preferably during the cDR.

b. The list shall include a detailed description of each handling device, its intended use, and whether it handles critical and/or non-critical hardware.

3.6.2 MHE Used to Handle Critical Hardware

3.6.2.1 MHE Used to Handle Critical Hardware General Requirements

3.6.2.1.1 MHE Used to Handle Critical Hardware Single Fault Tolerance. MHE used to handle critical hardware should have connector (pin, bolt, lug, rivet) and weld designs that are single fault tolerant against catastrophic failure. Reducing and/or eliminating the number of single failure point (SFP) connectors and SFP welds results in a significant reduction in the probability of a catastrophic event such as fatalities and the loss of national assets and a significant reduction in the cost of initial and periodic nondestructive examination.

3.6.2.1.2 MHE Used to Handle Critical Hardware Stress Analysis. A stress analysis shall be performed on all MHE used to handle critical hardware and the results reported in the MSPSP.

3.6.2.1.3 MHE Used to Handle Critical Hardware Single Failure Point Analyses.

a. All MHE used to handle critical hardware shall be analyzed for SFPs and the results reported in the MSPSP.

b. The use of SFP welds shall be avoided.

c. If the use of SFP welds cannot be avoided, they shall be designed to be easily inspected and shall be identified as SFP welds in the drawings.

d. A list of SFPs for each piece of equipment shall be submitted to Range Safety for review and approval as part of the MSPSP.

3.6.2.1.4 MHE Used to Handle Critical Hardware Nondestructive Examination Plans.

a. Non-destructive examination (NDE) plans shall be developed for each piece of MHE with SFP components or SFP welds. **NOTE:** NDE applies to all hooks and all MHE used to lift and support critical hardware.

b. The NDE plan for each applicable MHE shall include the following:

1. NDE technique and acceptance criteria to be used on each SFP component or SFP weld after initial and periodic proof load tests

2. Detailed engineering rationale for each technique and acceptance criteria

3. A determination of whether the MHE is a dedicated piece of equipment used for only one function or whether it is multi-purpose

4. The environment and/or conditions under which MHE will be used and stored

5. The existence of any SFP component and SFP weld materials susceptible to stress corrosion.

6. Corrosion protection and maintenance plans

c. The NDE plan shall be submitted to Range Safety for review and approval as soon as it is developed, but no later than the MHE PDR and shall be included as part of the MSPSP.

d. The following are acceptable NDE techniques and standards:

1. Surface inspection in accordance with MIL-STD-6866 or ASTM-E1444

2. Volumetric inspection in accordance with MIL-STD-453 or MIL-STD-2154

3. Visual inspections performed by persons trained and qualified. **NOTE:** Visual inspector qualification criteria and training shall be documented in a written procedure.

e. A non-inclusive list of standards that may be used to develop NDE acceptance criteria is provided below:

1. AWS D1.1, D1.2, D14.1, D14.2
2. MIL-STD-278
3. MIL-STD-2154
4. MIL-STD-1265
5. MIL-HDBK-1890
6. MIL-STD-2175
7. NAVSHIP 250-692-2
8. MSFC-STD-100
9. MSFC-STD-1249

3.6.2.1.5 MHE Accessibility for Initial and Periodic NDE. SFP components and welds shall be designed to be accessible for initial and periodic NDE.

3.6.2.1.6 MHE Used to Handle Critical Hardware Identification.

a. Marking Requirements. All MHE shall be permanently marked with the following information:

1. Serial number
2. Part number
3. Rated load
4. Weight of major component

b. Tagging Requirements

1. Following the proof load test, a non-sparking metal tag shall be securely attached to the MHE and shall be accessible for inspection.

2. The load test tags shall be marked (stamp-ed or etched) with the following minimum infomation:

(a) Part number, serial number, or other unique identifier
(b) Date of most recent load test
(c) Weight of test load
(d) Date of next load test
(e) Date of most recent NDE
(f) Date of next NDE
(g) A quality assurance or quality control indication certifying data on the tag

c. In addition, certification that all components have been proof load tested as an assembly shall be provided. **NOTE:** If the assembly is to be disassembled after proof testing, each component and subassembly shall be individually tagged.

3.6.2.1.7 MHE Used to Handle Critical Hardware Load Test Devices. Load tests shall be conducted with certified weights.

a. Load test weights shall be accurately identified and tagged with total weight (lb) and owner or agency identification number. **NOTE:** Calibrated load devices such as dynamometers may be used to test slings and other lifting devices except cranes.

b. Reinforcing steel (rebar) shall not be used for lift points.

c. The test weight shall be applied a minimum of 3 min.

3.6.2.1.8 MHE Used to Handle Critical Hardware Data Requirements. Specific data requirements for each type of MHE are identified throughout this section. These requirements fall into two categories: initial data requirements and recurring data requirements. The definition and processing requirements for initial and recurring data are described below:

a. Initial Data Requirements

1. All MHE shall have data that shows that the equipment meets the applicable design and initial test requirements.

2. These data requirements are identified in the **Initial Data Requirements** section for each type of MHE.

3. These data shall be submitted to Range Safety for review and approval prior to the first operational use of the equipment at the Ranges.

4. MHE design and initial test data shall be consolidated and included in the MSPSP as an appendix.

5. MHE design and initial test data shall be updated as required to reflect changes in design and testing.

b. Recurring Data Requirements

1. All MHE shall have data that shows that the equipment meets the applicable periodic testing requirements.

2. These data requirements are identified in the **Recurring Data Requirements** section for each type of MHE.

3. The periodic test plans shall be included in the MSPSP as an appendix.

4. In addition, periodic test plans and test results and MHE design and initial test data shall be maintained by the Range User in the MHE Recurring Test Data File.

5. MHE Recurring Test Data Files shall be made available to Range Safety upon request.

3.6.2.2 Cranes and Hoists Used to Handle Critical Hardware

3.6.2.2.1 Cranes and Hoists Used to Handle Critical Hardware Analyses.

a. An Operating and Support Hazard Analysis (O&SHA) shall be performed in accordance with a Range User and Range Safety jointly tailored System Safety Program. (See Appendix 1B.)

b. A Failure Mode Effects and Criticality Analysis (FMECA) shall be performed in accordance with a jointly tailored MIL-STD-1543 and MIL-STD-1629.

1. The FMECA shall identify failure conditions that could result in personnel injury, loss of load, or damage to critical hardware.

2. The FMECA shall encompass the complete power and control circuitry as well as the load path from hook to structure.

3. SFP components, SFP welds, and SFP modes shall be documented for tracking to elimination or acceptance.

3.6.2.2.2 Cranes and Hoists Used to Handle Critical Hardware Design Standards. All cranes and hoists shall comply with the following standards:

a. 29 CFR 1910

b. Crane Manufacturers Association of America (CMAA) 70 and 74 for Overhead Cranes and Hoists

c. ANSI B30 series for all Cranes and Hoists

d. Software control programs for cranes and hoists shall be designed and tested in accordance with a jointly tailored MIL-STD-2167 and MIL-STD-2168 and the **Computing Systems and Software** sections of this Chapter.

e. *National Electrical Code* (NEC) for all electrically powered cranes and hoists

f. *Material Handling Institute Standards*, as applicable

3.6.2.2.3 Additional WR Design Standards for Cranes and Hoists Used to Handle Critical Hardware.

a. All crane analyses, specifications, test plans, and test results shall be reviewed and approved by the Blue Ribbon Crane Committee (BRCC).

b. At VAFB, cranes not on VAFB exclusive Federal jurisdiction property also require inspection, testing, and certification in accordance with California Occupational Safety and Health (CAL-OSHA) requirements. **NOTE:** These requirements can be found in Title 8 of the *Administrative Code* and Chapter 4, *General Industry Safety Orders of CAL-OSHA* and the *BRCC Design Requirements Handbook for Electrically Powered Top Running Overhead and Underhung Traveling Cranes*

3.6.2.2.4 Cranes and Hoists Used to Handle Critical Hardware Selection Criteria.

a. The service classifications found in CMAA 70 and 74 shall be used as the basis for selecting cranes and hoists to be used on the Ranges.

b. Classification less than D shall be approved by Range Safety.

3.6.2.2.5 Cranes and Hoists Used in Hazardous Environments.

a. All cranes and hoists used in hazardous environments shall be designed to meet the hazard proofing requirements in the **Electrical Systems and Equipment Hazard Proofing** section of this Chapter.

b. Runway systems for overhead cranes and hoists shall be provided with non-sparking cable feed systems (festoon cable or double shoe sliding contractors) for supplying power to the bridge cranes.

c. Structural and mechanical parts shall not cause sparks during normal operation and sparks caused by emergency braking shall be prevented from falling into the work areas below.

3.6.2.2.6 Cranes and Hoists Component Accessibility.

a. Safe and adequate access to components to inspect, service, repair, or replace equipment shall be provided for during design. Consideration shall be given to the use of fixed platforms with guard rails in lieu of extensive use of personnel tie-offs.

b. The design shall provide for visual and physical accessibility of all safety critical SFP components and SFP welds.

3.6.2.2.7 Use of Rotation Resistant Wire Rope.

a. Rotation resistant wire rope shall not be used without specific permission from Range Safety.

b. Rotation resistant ropes shall not be used for any purposes with swivel links installed.

3.6.2.2.8 Use of Cast Iron. Cast iron and other similar brittle materials shall not be used in load bearing parts.

3.6.2.2.9 Hook Design.

a. All hooks shall be equipped with a positive latching mechanism to prevent accidental load disengagement.

b. All hooks used to lift loads containing propellants or ordnance shall have a grounding lug.

c. The initial throat opening of a hook shall be measured and permanent reference marks placed on each side of the hook. The distance between the marks shall be measured and recorded during periodic inspections for determination of the hook throat opening.

d. All hooks used to lift critical loads shall be insulated to allow not more than 70 microamperes of current flow per 1000 volts applied.

1. Hooks used for indoor cranes shall be rated for 10,000 volts.

2. Hooks used for outdoor cranes shall be rated for 50,000 volts.

3. Manufacturer test data shall show testing at two times the rated voltage.

4. Hook insulation shall be rated for RF attenuation of 50 to 1 at 50 megahertz.

e. Attachments such as handles and latch supports shall not be welded to a finished hook in field applications. If welding of an attachment such as these is required, it shall be done in manufacturing or fabrication prior to any required final heat treatment.

3.6.2.2.10 Overhead Crane and Hoist Design Requirements.

a. Reeving

1. Overhead cranes and hoists shall be capable of operating with a 5^{o} hoist angle without the load line contacting any structural member or obstructions and without the rope being pulled out of the drum or sheave grooves.

2. Cranes shall be double reeved with all load lines terminated at the equalizer and drum(s). **NOTE:** The equalizer system shall have the means to allow movement of the system to level the block.

(a) Cranes shall be reeved with one right lay rope and one left lay rope to cancel the block rotation tendency.

(b) The equalizer system shall have sufficient damping to sustain one load line breaking without shock loading the other rope enough to cause failure.

(c) The equalizer system shall be self-aligning with the load line.

3. All overhead cranes and hoists shall be equipped with a means (such as a level-wind device) for preventing the load line from coming out of the drum groove and overwrapping itself on the drum. **NOTE:** As an alternative, a warning device such as a spooling monitor that will activate an aural/visual warning and shutdown the crane when the load line comes out of the drum groove may be used.

4. Load lines shall be attached to the crane by a rope termination method that develops 100 percent of the rope strength.

b. Overhead Crane and Hoist Controls

1. Movement controls shall be of the "dead man" type.

2. Cab-operated cranes shall have a lever control, spring-loaded to the NEUTRAL position, and a RELEASE button that, if released, shall stop motion and require the control to be brought back to the NEUTRAL position to restart.

3. Cranes shall be provided with push button or lever type control switches.

4. Lever type switches shall be provided with a positive latch, that, in the OFF position, prevents the handle from being inadvertently moved to the ON position. **NOTE:** An OFF detent or spring return arrangement is not sufficient.

5. Movement controls shall have an inching (jog) capability only when the SPEED selector switch is in the slowest speed position. The slow speed shall be no greater than 2 ft per min.

6. All control panels shall have a lock-out feature such as a keyed switch to prevent unauthorized operation.

7. Crane controls shall permit the use of reversing or plugging as a means of controlling or stopping hoist, trolley, or bridge motion. **NOTE:** This capability should not be used during normal crane operations.

8. Pendant control stations shall be suspended by a strain relief chain or cable connected to protect the electrical conductors from strain.

9. The control station shall be located so the crane operator has direct line of sight to the load at all times. **NOTE:** If this is not possible, spotters or assistant operators shall have emergency stop capability at their location if inadvertent crane movement could result in personnel injury or death.

10. Control stations shall have the built-in capability to test the integrity of all indicator lamps and aural/visual warning devices.

11. Automatic cranes shall be designed so that all motion shall fail-safe if any malfunction of operation occurs.

12. Remotely-operated cranes shall function so that if the control signal for any crane motion becomes ineffective, the crane motion shall stop.

13. For systems where concurrent commands can be made, priority shall be provided for superior command or the control station shall be provided with a disconnect or key lockout feature. **NOTE:** The key lockout feature shall not preclude the emergency stop capability.

14. MIL-STD-1472 shall be used as guidance in designing the crane and hoist controls.

c. Overhead Crane and Hoist Limit Switches

1. All overhead cranes and hoists shall be equipped with 2 limit switches in the UP direction to prevent "two blocking" and 1 limit switch in the DOWN direction to prevent a slack rope condition.

(a) The first UP limit switch shall interrupt the movement control circuit and shall be reset by reversing the movement control.

(b) The second UP limit switch shall be a mechanical fail-safe switch that will interrupt power to the hoist mechanism and require maintenance personnel to reset.

2. Each bridge and trolley shall be equipped with limit switches that will first slow the bridge or trolley to “creep” speed and a second limit switch that will remove power and apply the brake before it engages the bumper or other mechanical stop.

d. Overhead Crane and Hoist Overload Indicators. All hoists shall be provided with an adjustable hoist overload detection device set to operate at 110 percent of rated load. When triggered, the device shall activate an overload indicator light and overload indicator horn

e. Overhead Crane and Hoist Brakes. Powered hoists shall have three independent brake systems: a control brake system, a holding brake system, and an emergency brake system on the hoist drum.

1. The emergency brake system shall automatically stop the drum if drum overspeed (110 percent of maximum rated lowering speed) is sensed.

2. All brake systems shall be capable of braking and holding at least 150 percent of torque exerted by full rated load on the hook.

3. Both the holding brake and the emergency brake shall be activated by the EMERGENCY STOP button.

4. Each brake system shall be designed to allow controlled lowering of the load.

5. Each brake system shall be capable of being tested independently in place. **NOTE:** A torque wrench fitting for purposes of testing the brakes shall be provided.

6. The application of multiple brake systems shall be synchronized to prevent overstressing or shock loading.

7. The holding and emergency brake systems shall be fail-safe; in other words, the brakes shall be applied automatically when power is removed.

f. Overhead Crane Bridge and Trolley Brakes. All overhead crane bridge and trolleys shall be equipped with fail-safe brakes in both directions. For specific requirements, see CMAA 70 and 74 and the ANSI B30 series.

g. Overhead Crane and Hoist Grounding and Bonding.

1. All cranes and hoists shall be grounded and bonded to provide critical hardware and personnel protection against electrical failures or lightning strikes.

2. Grounding and bonding between trolley, bridge, and runway shall use separate bonding conductors that may be run with electrical circuit conductors.

3. The contact between the wheels and frame shall not be considered a low resistance path to ground.

h. Overhead Crane Bridge and Trolley Movement Marking

1. Each overhead crane shall have the directions of its bridge and trolley movements displayed on the underside of the crane. These directions (North, East, South, and West) shall correspond to the directions on the operator station.

2. These markings shall be visible from the floor and any operator station.

i. Overhead Crane and Hoist Emergency Lowering System. All hoisting mechanisms used for lifting critical loads shall have a fail-safe capability for emergency lowering of the load in the event of a power failure or credible hoist mechanism malfunction.

j. Unique Cranes. All unique cranes such as TORUS, straddle, and winches used as hoists not covered in this document shall be justified to and approved by Range Safety on a case-by-case basis.

3.6.2.2.11 Mobile Cranes. The use of mobile cranes to lift critical hardware shall be justified to and approved by Range Safety on a case-by-case basis. At a minimum, mobile cranes used to lift critical hardware shall comply with the following:

a. ANSI B30.5, ANSI B30.15, OSHA 1926, and OSHA 1910.179

b. The following man-rated crane criteria shall be used for cranes used to lift critical hardware

1. A minimum of one upper limit switch

2. Deadman levers and controls on fixed control panels

3. The ability to deactivate free fall features

4. The ability to be derated to 50 percent of capacity

3.6.2.2.12 Portal Cranes. Portal cranes used to handle critical hardware shall be designed to incorporate the following items:

a. A load indicating device with the readout located in the cab

b. An upper limit switch at the boom point to prevent "two blocking"

c. A boom angle indicating device readable from the operator seat in the cab

3.6.2.2.13 Initial Test Requirements for Cranes and Hoists Used to Handle Critical Hardware.

a. General Test Requirements

1. Initial shop and field test plans and test results for cranes and hoists shall be submitted to Range Safety for review and approval as part of the crane and hoist Design and Initial Test Data in the MSPSP.

2. Any test anomaly discovered shall be evaluated by Range Safety as a cause for rejection.

3. Inspections and tests shall be performed by appointed or authorized persons. At the WR, these persons shall identify the federal or state office issuing certification authority and the expiration date of the certification authority.

4. At a minimum, the following tests shall be performed on cranes and hoists prior to their first operational use at the Ranges. Unless otherwise agreed to by Range Safety, all or part of these tests shall also be performed after a crane or hoist has been modified or repaired.

b. Testing Hooks Prior to Assembly on the Crane. The following tests shall be performed on the hook prior to assembly on the crane:

1. A proof load test shall be performed in accordance with ANSI B30.10.

2. After the proof load test, volumetric and surface NDE shall be performed on the hook and its shank, bolt, and nut.

c. Overhead Crane and Hoist Initial Functional Test (No-Load). Prior to and after any load testing, the following no-load tests shall be performed:

1. A complete functional test of all control systems, safety devices, and warning indicators shall be performed after the crane is assembled on the Range.

2. The hook insulator shall be tested, as installed, to verify that the insulator complies with the design specification.

3. If a spooling monitor is installed, a test shall be performed to verify that the monitor sounds an alarm and shuts down the crane when the load comes out of the drum groove.

4. A test shall be performed to verify that the crane can operate with a 5^o degree hoist angle without the load line contacting any structural member or obstruction and without the rope being pulled out of the drum or sheeve grooves.

5. A test shall be performed to verify that all crane controls levers are deadman-type controls.

6. A test shall be performed to verify that the crane operator station or stations are capable of performing an integrity check of all indicator lamps and aural/visual warning devices.

d. Overhead Crane and Hoist Load Tests. The following tests shall be performed by the manufacturer or a designated representative on site at the Ranges after complete installation of the crane:

1. Overhead cranes and hoists shall be proof load tested to 125 percent of the rated load. The test shall be performed in the following sequence:

(a) The test weight shall be hoisted approximately 2 ft and suspended for a minimum of 3 min to verify that drum rotation and test weight drift, as measured, are within acceptable limits.

(b) The hoist overload detection devices shall be tested to verify that they activate when the test weight is greater than 110 percent of rated load.

(c) Electrical power shall be removed from the crane so that the holding and emergency drum brakes are engaged. The brakes shall be manually released in such a manner that each individual brake demonstrates its ability to hold the entire test weight without slipping. Electrical power shall be reapplied.

(d) The test weight shall be raised to the maximum height and then lowered in three increments, stopping each time to verify there is no uncommanded drum rotation or test weight lowering.

(e) The test weight shall be transported by the trolley for the full length of the bridge.

(f) The test weight shall be transported the full length of the runway in one direction with the trolley as close to the extreme right hand of the bridge as practical and in the other direction with the trolley as close to the extreme left hand of the bridge as practical.

2. Overhead cranes and hoists shall be subjected to the following tests at 100 percent of rated load:

(a) The test weight shall be hoisted approximately 2 ft and suspended for a minimum of 3 min to verify that drum rotation and test weight drift, as measured, are within acceptable limits.

(b) The test weight shall be raised to sufficient height and at least one emergency stop shall be made at the fastest lowering speed to verify that brake application meets specification requirements.

(c) The test weight shall be moved throughout the complete operating envelope of the overhead crane and hoist, stopping and starting at various locations to verify smooth operation.

(d) Crane controls shall be tested to verify that the use of reversing or plugging can control or stop the hoist, trolley, and bridge motion.

(e) Bridge and trolley brakes shall be tested to verify that they function in accordance with CMAA 70 and 74 and ANSI B30 Series requirements.

(f) The hoist emergency load lowering system shall be tested to verify that it is fail-safe and functions properly.

(g) Bridge, trolley, and hoists shall be tested at each specified speed, including bumping and jogging.

e. Crane and Hoist No-Load Test Requirements. The following tests shall be performed after load testing:

1. Hoist brake overspeed sensing devices shall be tested to verify they function properly.

2. Bridge, trolley, and hoist limit switches shall be tested in each direction.

3. The fail-safe design of the bridge and trolley brakes shall be tested by turning the power off while moving the bridge and trolley in each direction.

f. Crane and Hoist NDE Requirements. The following NDE tests shall be performed as indicated:

1. All SFP components and SFP welds on the crane and hoist and support structures shall be volumetrically and surface inspected prior to the proof load test.

2. After the 125 percent proof load test, volumetric and surface NDE testing shall be performed on all crane and hoist SFP components and SFP welds including those located on support structures. **NOTE:** SFP welds that cannot be inspected after the crane proof load test shall be identified and a risk assessment submitted to Range Safety for review and approval.

3. Volumetric and surface NDE testing shall be performed on 4 in. or 10 percent, whichever is less, of every continuous non-SFP weld on support structures for overhead cranes and hoists in accordance with AWS D14.1, paragraph 8.9.5.

4. After completion of the 125 percent proof load test, surface NDE testing shall be performed on the exposed portions of hooks.

g. Crane and Hoist Inspection Requirements. Cranes and hoists shall be visually inspected per ANSI and Range Safety inspection criteria.

3.6.2.2.14 Cranes and Hoists Used to Handle Critical Hardware Periodic Test Requirements.

a. General Periodic Test Requirements.

1. Periodic test plans and test results for cranes and hoists shall be submitted to Range Safety for review and approval as part of the MSPSP.

2. At a minimum, the following tests shall be performed on cranes and hoists annually. These tests shall be accomplished within the calendar month in which they are due.

b. Overhead Crane and Hoist Annual No-Load Functional Test. A complete functional test of all control systems, safety devices, and warning indicators shall be performed after the annual load test.

c. Overhead Crane and Hoist Annual 100 Percent Rated Load Tests. Overhead cranes and hoists shall be load tested to 100 percent of the rated load. The test shall be performed in the following sequence:

1. The test weight shall be hoisted approximately 2 ft and suspended for a minimum of 3 min to verify hoist drum rotation and test weight drift, as measured, are within acceptable limits.

2. The hoist overload detection devices shall be tested to verify that they activate when the test weight is greater than 110 percent of rated load.

3. Electrical power shall be removed from the crane so that the holding and emergency drum brakes are engaged. The brakes shall be manually released in such a manner that each individual brake demonstrates its ability to hold the entire test weight within acceptable drift. Electrical power shall be reapplied.

4. The test weight shall be raised to the maximum height and then lowered in three increments, stopping each time to verify there is no uncommanded drum rotation or test weight lowering.

5. The test weight shall be transported by the trolley for the full length of the bridge.

6. The test weight shall be transported the full length of the runway in one direction with the trolley as close to the extreme right hand of the bridge as practical and in the other direction with the trolley as close to the extreme left hand of the bridge as practical.

7. The test weight shall be moved throughout the complete operating envelope of the overhead crane and hoist, stopping and starting at various locations to verify smooth operation.

8. Crane controls shall be tested to verify that the use of reversing or plugging can control or stop the hoist, trolley, and bridge motion.

9. Bridge and trolley brakes shall be tested to verify that they function in accordance with CMAA 70 and 74 and ANSI B30 Series requirements.

10. The hoist emergency load lowering system shall be tested to verify that it is fail-safe and functions properly. The load shall not be lowered more than a few feet. The brakes shall be inspected and adjusted afterwards.

11. Bridge, trolley, and hoists shall be tested at each available specified speed, including bumping and jogging.

d. Crane and Hoist Annual NDE Requirements. The following NDE tests shall be performed as indicated:

1. After completion of the 100 percent load test, surface NDE testing shall be performed on the exposed portions of hooks.

2. After completion of the 100 percent load test, volumetric and surface NDE testing shall be performed on all modified and repaired SFP components and SFP welds located on overhead crane and hoist support structures.

3. NDE shall be performed in accordance with the Range Safety approved NDE plan on all SFP components and SFP welds located on overhead and hoist support structures.

e. Crane and Hoist Annual Inspection Requirements. Cranes and hoists shall be visually inspected per ANSI and Range Safety inspection criteria.

3.6.2.2.15 Cranes and Hoists Used to Handle Critical Hardware Initial Data Requirements. At a minimum, the following data is required as part of the Crane and Hoist Design and Initial Test Data File:

a. SFP Analysis

b. O&SHA

c. FMECA

d. NDE plans and test results for crane hooks and SFP components and SFP welds on overhead crane and hoist support structures and 10 percent of non-SFP welds on overhead crane and hoist support structures

e. Software test plans and results if applicable

f. Initial crane and hoist test plans and test results

g. Stress analysis for crane and hoist support structures

h. Crane specifications

i. Certificate of conformance to specifications

j. Computer-aided design (CAD) output data, if available

3.6.2.2.16 Cranes and Hoists Used to Handle Critical Hardware Recurring Data Requirements. At a minimum, the following recurring data is required as part of the Crane and Hoist Recurring Test Data File:

a. Crane and hoist design and initial test data

b. NDE test results for crane hook and SFP components and SFP welds on crane support struct-ures

c. Periodic crane and hoist test plans and tests results

d. Crane design and test data updates

3.6.2.3 Sling Assemblies Used to Handle Critical Hardware

3.6.2.3.1 Sling Assemblies Used to Handle Critical Hardware Design Standards. All slings shall be designed and fabricated in accordance with ANSI B30.9 and 29 CFR 1910.184.

3.6.2.3.2 Sling Assemblies Used to Handle Critical Hardware Design Requirements.

a. All slings shall be designed with an ultimate factor of safety of 5 or higher.

b. All synthetic slings shall be designed with an ultimate factor of safety of 10 or higher.

c. Natural fiber rope or natural fiber web slings shall not be used.

d. Carbon steel or wrought iron chain slings shall not be used.

e. Wire rope slings shall be formed with swaged or zinc poured sockets or spliced eyes.

f. Wire rope clips or knots may not be used to form slings.

g. Rotation resistant rope shall not be used for fabricating slings.

3.6.2.3.3 Sling Assemblies Used to Handle Critical Hardware Marking. Sling assemblies used to handle critical hardware shall be marked in accordance with the **MHE Used to Handle Critical**

Hardware Identification section of this Chapter.

3.6.2.3.4 Sling Assemblies Used to Handle Critical Hardware Initial Test Requirements. At a minimum, the following tests shall be performed on sling assemblies prior to first operational use at the Ranges:

a. The proof load for single-leg slings and endless slings shall be two times the vertical orientation rated capacity.

b. The proof load for multiple leg bridle slings shall be applied to the individual legs and shall be two times the vertical orientation rated capacity of a single-leg sling of the same size, grade, and construction of rope.

c. Chain falls shall be proof load tested to 125 percent of rated load in accordance with ANSI/ASME B30.16.

d. After the proof load test, volumetric and surface NDE testing shall be performed on all sling assembly SFP components such as pins, bolts, shackles, and links.

e. Sling assemblies shall be visually inspected in accordance with ANSI and Range Safety inspection criteria.

3.6.2.3.5 Sling Assemblies Used To Handle Critical Hardware Periodic Tests. At a minimum, the following tests shall be performed on sling assemblies annually. Unless otherwise agreed to by Range Safety, these tests shall also be performed after a sling assembly has been modified or repaired:

a. Sling assemblies shall be proof load tested to 200 percent of rated load.

b. Chain falls shall be proof load tested to 100 percent of rated load.

c. After the proof load test, NDE testing shall be performed on all sling assembly SFP components in accordance with the Range Safety approved NDE plan.

d. After the proof load test, volumetric and surface NDE testing shall be performed on all modified and repaired sling assembly SFP components.

e. Sling assemblies shall be visually inspected in accordance with ANSI and Range Safety inspection criteria.

3.6.2.3.6 Sling Assemblies Used to Handle Critical Hardware Initial Data Requirements. At a minimum, the following data is required as part of the Sling Design and Initial Test Data:

a. SFP analysis

b. NDE plan and test results for SFP components

c. Initial proof load test plan and test results

d. Stress analysis

3.6.2.3.7 Sling Assemblies Used to Handle Critical Hardware Recurring Data Requirements. At a minimum, the following data is required as part of the Sling Assembly Recurring Test Data File:

a. Sling assembly design and initial test data

b. NDE test results for SFP components

c. Periodic proof load test plan and test results

d. Sling design and test data updates

3.6.2.4 Hydrasets and Load Cells Used to Handle Critical Hardware

3.6.2.4.1 Hydrasets and Load Cells Used to Handle Critical Hardware Design Requirements.

a. All hydrasets and load cells shall be designed with an ultimate factor of safety of 5.

b. If pneumatically controlled hydrasets are used, the following items are required:

1. Installation of a fail-safe check valve in the hydraset control line to prevent a drop of the load due to loss of pneumatic control pressure

2. Installation of a fast acting safety shutoff valve downstream of the load regulator to provide positive control of the hydraset when no motion is desired

c. Hydrasets shall be designed to mechanically support the rated load if the hydraset hydraulics fail.

d. Load cells shall be designed to support the rated load if the load measuring device fails.

e. Hydrasets and load cells shall not be used to lift loads in excess of 50 percent rated load if the device can not be proof load tested to 200 percent of rated load. **NOTE:** If the hydraset or load cell is derated, the identification tag shall be marked with the derated load.

f. For cranes and hoists with load cells designed into the load path, location of the load cell shall be approved by Range Safety.

3.6.2.4.2 Hydrasets and Load Cells Used to Handle Critical Hardware Initial Test Requirements. At a minimum, the following tests shall be performed on all hydrasets and load cells prior to first operational use at the Ranges:

a. Hydrasets and load cells shall be proof load tested to 200 percent of rated load.

b. After the proof load test, volumetric and surface NDE testing shall be performed on all SFP components and SFP welds.

3.6.2.4.3 Hydrasets and Load Cells Used to Handle Critical Hardware Periodic Test Requirements. At a minimum, the following tests shall be performed on all hydrasets and load cells annually. Unless otherwise agreed to by Range Safety, these tests shall also be performed after a hydraset and load cell has been modified or repaired:

a. Hydrasets and load cells shall be proof load tested to 125 percent of rated load and calibrated.

b. After the proof load test, volumetric and surface NDE testing shall be performed on all modified and repaired SFP components and SFP welds.

c. After the proof load test, NDE shall be performed on all hydraset and load cell SFP components and SFP welds in accordance with the Range Safety approved NDE plan.

3.6.2.4.4 Hydrasets and Load Cells Used to Handle Critical Hardware Initial Data Requirements. At a minimum, the following data is required as part of the Hydraset and Load Cell Design and Initial Test Data:

a. SFP analysis

b. NDE plan and test results for SFP components and SFP welds

c. Initial proof load test plan and test results

d. Stress analysis

3.6.2.4.5 Hydrasets and Load Cells Used to Handle Critical Hardware Recurring Data Requirements. At a minimum, the following data is required as part of the Hydraset and Load Cell Recurring Test Data File:

a. Hydraset and load cell design and initial test data

b. NDE test results for SFP components and SFP welds

c. Periodic proof load test plan and test results

d. Design and test data updates

3.6.2.5 Handling Structures Used to Handle Critical Hardware

3.6.2.5.1 Handling Structures Used to Handle Critical Hardware Design Standards.

a. Structural mechanisms such as spin tables, rotating devices, and portable launch platforms shall be subjected to a hazard analysis in accordance with a Range User and Range Safety jointly tailored System Safety Program Plan (see Appendix 1B.)

b. All structural lifting beams shall meet ANSI B30.20.

3.6.2.5.2 Handling Structures Used to Handle Critical Hardware Design Requirements.

a. All handling structures, except portable launch support frames, shall be designed with a yield factor of safety of 3.

b. Material used in the construction of handling structures shall have a yield strength less than or equal to 85 percent of ultimate strength. **NOTE:** If this criteria cannot be met, the structure shall be designed with an ultimate factor of safety of 5.

c. Portable and movable launch support frames may be designed with a yield factor of safety of 2 if weight is a consideration; however, NDE requirements may increase.

3.6.2.5.3 Handling Structures Used to Handle Critical Hardware Marking Requirements. Handling structures used to handle critical hardware shall be marked in accordance with the **MHE Used to Handle Critical Hardware Identification** section of this Chapter.

3.6.2.5.4 Handling Structures Used to Handle Critical Hardware Initial and Periodic Test Requirements.

a. New or modified and repaired handling structures shall be tested initially and periodically in accordance with either Option 1 or Option 2 of Appendix 3B. *EXCEPTION: For portable launch support frames with a yield factor of safety of less than 3, Step 17 in Option 2 is changed to read "Proof test to 150 percent times rated load" and Step 16 is eliminated.*

b. Initial tests shall be performed following modification and repair or prior to first operational use at the Ranges.

3.6.2.5.5 Handling Structures Used to Handle Critical Hardware Initial Data Requirements. At a minimum, the following data is required as part of the Handling Structure Design and Initial Test Data:

a. SFP analysis

b. NDE plan and test results for SFP and non-SFP components and welds.

c. Initial proof load test plan and test results

d. Stress analysis for structures

e. Safe-life analysis if Option 2 of Appendix B is chosen

f. O&SHA and FMECA analyses for structural mechanisms such as spin tables, rotating structures, and portable launch support frames

3.6.2.5.6 Handling Structures Used to Handle Critical Hardware Recurring Data Requirements. At a minimum, the following recurring data is required as part of the Handling Structure Recurring Test Data File:

a. Handling structure design and initial test data

b. NDE test results for SFP components and SFP welds

c. Periodic test plans and test results

d. Design and test data updates

3.6.2.6 Flight Hardware Used to Lift Critical Loads

3.6.2.6.1 Flight Hardware Used to Lift Critical Loads Design Requirements. Lift fittings such as lugs and plates permanently attached to flight hardware shall be designed so that the loss of one fitting and/or structure will not result in the dropping of the load. **NOTE:** If this requirement can not be met, the minimum ultimate factor of safety shall be 1.5.

3.6.2.6.2 Flight Hardware Used to Lift Critical Loads Initial Test Requirements. At a minimum, the following tests shall be performed on permanently attached flight hardware lift fittings prior to their first operational use at the Ranges:

a. Lift fittings shall be load tested to 100 percent of rated load as an integral part of structural flight load testing.

b. After the load test, volumetric and surface NDE testing shall be performed on all lift fitting SFP components and SFP welds.

3.6.2.6.3 Flight Hardware Used to Lift Critical Loads Initial Data Requirements. At a minimum, the following data is required as part of the Flight Hardware Lifting Equipment Design and Initial Test Data:

a. SFP analysis

b. NDE plan and test results for SFP components and SFP welds

c. Initial proof load test plan and test results

d. Stress analysis

3.6.2.7 Removable, Extendible, and Hinged Personnel Work Platforms

3.6.2.7.1 Removable, Extendible, and Hinged Personnel Work Platform Design Requirements.

a. Safety factors for the design of platforms shall be consistent with those of the overall structures on which they are permanently mounted. In no case shall the safety factors be less than that of the overall structure, the applicable national consensus standard American Institute of Steel Construction (AISC), Aluminum Association, or yield factor of safety of 2, whichever is greater.

b. Hinges, attaching points, and other high stress or abuse prone components and their interface hardware shall be designed with a yield factor of safety of at least 3. Yield strength shall be less than or equal to 85 percent of ultimate strength or the ultimate factor of safety shall be 5.

c. A minimum of 60 lb per ft^2 shall be used for the uniformly distributed live load.

d. A minimum of 2000 lb shall be used for point loading.

e. A minimum load of 300 lb per occupant shall be used.

f. Guardrail systems and toe boards shall be provided and designed in accordance with OSHA 1910.23.

g. Man-rated baskets used with cranes shall be certified and load test in accordance with OSHA 1926.550.

h. Personnel platforms shall have a means of positive mechanical restraint when in the open, raised, folded back, or use position to prevent unintentional movement. **NOTE:** Bolting is not acceptable; latches, levers, or pins with lanyards shall be used.

3.6.2.7.2 Removable, Extendible, and Hinged Personnel Work Platforms Marking Requirements.

a. All platforms shall be clearly marked with 2-in. letters minimum indicating maximum load capacity.

b. In addition, the following information shall be imprinted on a metal tag attached to the platform:

1. Maximum distributed load

2. Maximum concentrated load (point load)

c. A load test tag accessible for inspection shall be provided on the platform.

3.6.2.7.3 Removable, Extendible, and Hinged Personnel Work Platform Initial Test Requirements. At a minimum, the following tests shall be performed on all personnel work platforms prior to their first operational use at the Ranges:

a. Platforms shall be proof load tested to 125 percent of rated load.

b. After the proof load test, volumetric and surface NDE testing shall be performed on all personnel work platform SFP components and SFP welds.

3.6.2.7.4 Removable, Extendible, and Hinged Personnel Work Platform Periodic Test Requirements. At a minimum, the following tests shall be performed on all personnel work platforms annually:

a. Visual inspection shall be performed on all hinges, attaching points, and other high stress or abuse prone components.

b. NDE shall be performed on all personnel work platform SFP components and SFP welds in accordance with the Range Safety approved NDE plan.

c. After the proof load test, volumetric NDE testing shall be performed on all modified and repaired SFP components and SFP welds.

d. Unless otherwise agreed to by Range Safety, personnel work platforms that have been modified and/or repaired shall be proof load tested to 125 percent of rated load.

3.6.2.7.5 Removable, Extendible, and Hinged Personnel Work Platform Initial Data Requirements. At a minimum, the following data is required as part of the Personnel Work Platform Design and Initial Test Data:

a. SFP analysis

b. NDE plan and test results for SFP and non-SFP components and welds

c. Initial proof load test plan and test results

d. Stress analysis

3.6.2.7.6 Removable, Extendible, and Hinged Personnel Work Platform Recurring Data Requirements. At a minimum, the following recurring data is required as part of the Personnel Work Platform Recurring Test Data:

a. Platform design and initial test data

b. NDE test results for SFP components and SFP welds

c. Periodic proof test plans and results

d. Design and test data updates

3.6.3 MHE Used to Handle Non-Critical Hardware

3.6.3.1 Material Handling Equipment Used to Handle Non-Critical Hardware General Requirements

3.6.3.1.1 MHE Used to Handle Non-Critical Hardware Identification.

a. Marking Requirements. All MHE shall be permanently marked with the following information:

1. Serial number

2. Part number

3. Rated load

b. Tagging Requirements

1. Following the rated load test, a durable tag shall be securely attached to the MHE and shall be accessible for inspection.

2. The load test tags shall be marked (stamped or etched) with the following minimum information:

(a) Part Number, Serial Number, or other unique identifier

(b) Date of most recent load test

(c) Weight of test load

(d) Date of next load test

(e) Date of most recent NDE

(f) Date of next NDE

c. In addition, certification that all components have been proof load tested as an assembly shall be provided. **NOTE:** If the assembly is to be disassembled after proof testing, each component and subassembly shall be individually tagged.

3.6.3.1.2 MHE Used to Handle Non-Critical Hardware Load Test Devices.

a. Load tests shall be conducted with certified weights. **NOTE:** Calibrated load devices such as dynamometers may be used to test slings and other lifting devices except cranes.

b. These weights shall be accurately identified and tagged with total weight (lb) and owner or agency identification number.

c. Reinforcing steel (rebar) shall not be used for lift points.

d. The test weight shall be applied for a minimum of 3 min.

3.6.3.1.3 MHE Used to Handle Non-Critical Hardware Data Requirements. Specific data requirements for each type of MHE are identified throughout this section. These requirements fall into two categories: initial data requirements and recurring data requirements. The definition and processing requirements for initial and recurring data are described below:

a. Initial Data Requirements

1. All MHE shall have data that shows that the equipment meets the applicable design and initial test requirements.

2. These data requirements are identified in the **Initial Data Requirements** section for each type of MHE.

3. These data shall be consolidated into an MHE Design and Initial Test Data Package and maintained by the Range User.

4. The MHE Design and Initial Test Data Package shall be updated as required to reflect changes in design and tests.

5. The MHE Design and Initial Test Data Package shall be submitted to Range Safety for review and approval prior to the first operational use of the equipment at the Ranges.

b. Recurring Data Requirements

1. All MHE shall have data that shows that the equipment meets the applicable periodic testing requirements.

2. These data requirements are identified in the **Recurring Data Requirements** section for each type of MHE.

3. The periodic test plans shall be included in the MHE Design and Initial Test Data Package. In addition, the periodic test plans and test results and the MHE Design and Initial Test Data Package shall be maintained by the Range User in the MHE Recurring Test Data File.

4. MHE Recurring Test Data Files shall be made available to Range Safety upon request.

3.6.3.2 Cranes and Hoists Used to Handle Non-Critical Hardware

3.6.3.2.1 Cranes and Hoists Used to Handle Non-Critical Hardware Design Standards. All cranes and hoists shall comply with the following industry standards:

a. 29 CFR 1910

b. CMAA 70 and 74 for overhead cranes and hoists

c. ANSI B30 series for all cranes and hoists

d. NEC for all electrically powered cranes and hoists

e. *Material Handling Institute Standards*, as applicable.

3.6.3.2.2 Additional WR Design Standards for Cranes and Hoists Used to Handle Non-Critical Hardware.

a. All crane specifications, test plans, and test results shall be reviewed and approved by the BRCC.

b. At VAFB, cranes not on VAFB Exclusive Federal Jurisdiction property also require inspections, testing, and certification in accordance with CAL-OSHA requirements. **NOTE:** These requirements can be found in Title 8 of the *Administrative Code* and Chapter 4, *General Industry Safety Orders* of CAL-OSHA and the *BRCC Design Requirements Handbook for Electrically Powered Top Running Overhead and Underhung Traveling Cranes.*

3.6.3.2.3 Cranes and Hoists Used to Handle Non-Critical Hardware Selection Criteria. The service classifications found in CMAA 70 and 74, Chapter 2 shall be used as the basis for selecting cranes and hoists to be used on the Ranges.

3.6.3.2.4 Cranes and Hoists Component Accessibility.

a. Safe and adequate access to components to inspect, service, repair, or replace equipment shall be provided for during design. Consideration shall be given to the use of fixed platforms with guard rails in lieu of the extensive use of personnel tie-offs.

b. The design shall provide for visual and physical accessibility of all SFP components and SFP welds safety critical parts.

3.6.3.2.5 Use of Rotation Resistant Wire Rope.

a. Rotation resistant wire rope shall not be used without specific permission from Range Safety.

b. Rotation resistant ropes shall not be used for any purposes with swivel links installed.

3.6.3.2.6. Use of Cast Iron. Cast iron and other similar brittle materials shall not be used in load bearing parts.

3.6.3.2.7 Hooks.

a. All hooks shall be equipped with a positive latching mechanism to prevent accidental load disengagement.

b. The initial throat opening of a hook shall be measured and permanent reference marks placed on each side of the hook. The distance between the marks shall be measured and recorded during periodic inspections for determination of the hook throat opening.

c. Attachments such as handles and latch supports shall not be welded to a finished hook in a field application. **NOTE:** If welding of an attachment such as these is required, it shall be done in manufacturing or fabrication prior to any required final heat treatment.

3.6.3.2.8 Overhead Cranes and Hoists Used to Handle Non-Critical Hardware Design Requirements.

a. Reeving

1. For double reeved overhead cranes, equalizer sheaves shall be self-aligning with the load line.

2. Load lines shall be attached to the crane by a rope termination method that develops 100 percent of the rope strength.

b. Overhead Crane and Hoist Controls

1. Movement controls shall be of the "dead man" type.

2. Cranes shall be provided with push button or lever type control switches.

3. Movement controls shall have an inching (jog) capability only when the SPEED selector switch is in the slowest speed position.

4. Pendant control stations shall be suspended by a strain relief chain or cable to protect the electrical conductors from strain.

5. The control station shall be located so that the crane operator has direct line of sight to the load at all times.

c. Overhead Crane and Hoist Limit Switches. All overhead cranes and hoists shall be equipped with 2 limit switches in the UP direction to prevent "two blocking" and 1 limit switch in the DOWN direction to prevent a slack rope condition.

1. The first UP limit switch shall interrupt the movement control circuit and shall be reset by reversing the movement control.

2. The second UP limit switch shall be a mechanical fail-safe switch that will interrupt power to the hoist mechanism and require maintenance personnel to reset.

d. Overhead Crane Bridge and Trolley Brakes. All overhead crane bridge and trolleys shall be equipped with fail-safe brakes in both directions. For specific requirements, see CMAA 70 and 74 and the ANSI B30 series.

e. Overhead Crane and Hoist Grounding

and Bonding

1. All cranes and hoists shall be grounded and bonded to provide critical hardware and personnel protection against electrical failures or lightning strikes.

2. Grounding and bonding between trolley, bridge, and runway shall use separate bonding conductors that may be run with electrical circuit conductors.

3. The contact between the wheels and frame shall not be considered a low resistance path to ground.

f. Overhead Crane Bridge and Trolley Movement Marking

1. Each overhead crane shall have the directions of its bridge and trolley movements displayed on the underside of the crane. These directions (North, East, South, and West) shall correspond to the directions on the operator station.

2. These markings shall be visible from the floor and any operator station.

3.6.3.2.9 Cranes and Hoists Used to Handle Non-Critical Hardware Initial Test Requirements.

a. General Initial Shop and Field Test Requirements

1. Initial test plans and test results for cranes and hoists shall be submitted to Range Safety for review and approval as part of the Crane and Hoist Design and Initial Test Data Package in the MSPSP.

2. Any test anomaly discovered shall be evaluated by Range Safety as a cause for rejection.

3. Inspections and tests shall be performed by appointed or authorized persons. At the WR, these persons shall identify the federal or state office issuing certification authority and the expiration date of the certification authority.

4. At a minimum, the following tests shall be performed on cranes and hoists prior to their first operational use at the Ranges. **NOTE**: Unless otherwise agreed to by Range Safety, all or part of these tests shall also be performed after a crane and hoist has been modified or repaired.

b. Testing Hooks Prior to Assembly on the Crane. The following tests shall be performed on the hook prior to assembly on the crane:

1. A proof load test shall be performed in accordance with ANSI B30.10.

2. After the proof load test, a surface NDE shall be performed on the hook and its shank, bolt, and nut.

c. Portal Crane Proof Load Test. Portal cranes shall be proof load tested to 125 percent of the rated load.

d. Mobile Crane Proof Load Test. Mobile cranes shall be proof load tested to 110 percent of the rated load.

e. Overhead Crane and Hoist Initial Functional Test (No-Load). A complete functional test of all control systems, safety devices, and warning indicators shall be performed after the crane is assembled at the Ranges and after load testing.

f. Overhead Crane and Hoist Load Tests. The following tests shall be performed by the manufacturer or a designated representative on site at the Ranges after complete installation of the crane:

1. Overhead cranes and hoists shall be proof load tested to 125 percent of the rated load. The test shall be performed in the following sequence:

(a) The test weight shall be hoisted approximately 2 ft and suspended for a minimum of 3 min to verify hoist drum rotation and test weight drift are within acceptable limits.

(b) The test weight shall be raised to the maximum height and then lowered in three increments, stopping each time to verify there is no uncommanded drum rotation or test weight lowering.

(c) The test weight shall be transported by the trolley for the full length of the bridge.

(d) The test weight shall be transported the full length of the runway in one direction with the trolley as close to the extreme right hand of the bridge as practical and in the other direction with the trolley as close to the extreme left hand of the bridge as practical.

2. Overhead cranes and hoists shall be subjected to the following tests at 100 percent of rated load. The test shall be performed in the following sequence:

(a) The test weight shall be hoisted approximately 2 ft and suspended for a minimum of 3 min to verify hoist drum rotation and test weight drift are within acceptable limits.

(b) The test weight shall be moved throughout the complete operating envelope of the overhead crane and hoist, stopping and starting at various locations to verify smooth operation.

(c) Bridge and trolley brakes shall be tested to verify that they function in accordance with CMAA 70 and 74 and ANSI B30 Series re-

quirements.

(d) The test weight shall be raised to sufficient height and at least one emergency stop shall be made at the fastest lowering speed to verify that brake application is positive and effective.

(e) Bridge, trolley, and hoists shall be tested at each specified speed, including bumping and jogging.

g. Crane and Hoist NDE Requirements. After completion of the 125 percent proof load test, surface NDE shall be performed on the exposed portions of overhead, portal, and mobile crane hooks.

h. Crane and Hoist Inspection Requirements. Cranes and hoists shall be visually inspected in accordance with ANSI and Range Safety inspection criteria.

3.6.3.2.10 Cranes and Hoists Used to Handle Non-Critical Hardware Periodic Test Requirements.

a. General Periodic Test Requirements

1. Periodic test plans for cranes and hoists shall be submitted to Range Safety for review and approval as part of the MSPSP.

2. At a minimum, the following tests shall be performed on cranes and hoists every four years unless as otherwise approved by Range Safety.

b. Overhead Crane and Hoist Functional Test (No-Load). A complete functional test of all control systems, safety devices, and warning indicators shall be performed after load testing.

c. Portal and Mobile Crane Load Tests. Portal and mobile cranes shall be load tested to 100 percent of rated load.

d. Overhead Crane and Hoist 100 Percent Rated Load Tests. Overhead cranes and hoists shall be load tested to 100 percent of the rated load. The test shall be performed in the following sequence:

1. The test weight shall be hoisted approximately 2 ft and suspended for a minimum of 3 min to verify hoist drum rotation and test weight drift are within acceptable limits.

2. The test weight shall be raised to the maximum height and then lowered in three increments, stopping each time to verify there is no uncommanded drum rotation or test weight lowering.

3. The test weight shall be transported the full length of the runway in one direction with the trolley as close to the extreme right hand of the bridge as practical and in the other direction with the trolley as close to the extreme left hand of the bridge as practical.

4. The test weight shall be raised to sufficient height and at least one emergency stop shall be made at the fastest lowering speed to verify that brake application is positive and effective.

5. The test weight shall be moved throughout the complete operating envelope of the overhead crane and hoist, stopping and starting at various locations to verify smooth operation.

6. Bridge and trolley brakes shall be tested to verify that they function in accordance with CMAA 70 and 74 and ANSI B30 Series requirements.

7. Bridge, trolley, and hoists shall be tested at each specified speed, including bumping and jogging.

e. Crane and Hoist NDE Requirements. After completion of the proof load test, surface NDE shall be performed on the exposed portions of overhead, portal, and mobile crane hooks.

f. Crane and Hoist Inspection Requirements. Cranes and hoists shall be visually inspected at required intervals in accordance with ANSI and 30/45 SW inspection criteria.

3.6.3.2.11 Cranes and Hoists Used to Handle Non-Critical Hardware Initial Data Requirements. At a minimum, the following data is required as part of the Crane and Hoist Design and Initial Test Data Package:

a. NDE plan and test results for crane hooks

b. Initial crane and hoist test plans and test results

c. Crane specifications

d. Certification of conformance to specifications

3.6.3.2.12 Cranes and Hoists Used to Handle Non-Critical Hardware Recurring Data Requirements. At a minimum, the following recurring data is required as part of the Crane and Hoist Recurring Test Data File:

a. Crane and hoist design and initial test data

b. NDE test results for crane hooks

c. Periodic crane and hoist test plans and test results

d. Crane and Hoist Design and test data updates

3.6.3.3 Sling Assemblies Used to Handle Non-Critical Hardware

3.6.3.3.1 Sling Assemblies Used to Handle Non-Critical Hardware Design Standards. All slings shall be designed and fabricated in accordance with ANSI B30.9 and 29 CFR 1910.184.

3.6.3.3.2 Sling Assemblies Used to Handle Non-Critical Hardware Design Requirements.

a. All slings shall be designed with an ultimate factor of safety of 5 or higher.

b. Carbon steel or wrought iron chain slings shall not be used.

c. Wire rope slings shall be formed with swaged or zinc poured sockets or spliced eyes.

d. Wire rope clips or knots may not be used to form slings.

e. Rotation resistant rope shall not be used for fabricating slings.

3.6.3.3.3 Sling Assemblies Used to Handle Non-Critical Hardware Marking Requirements. Sling assemblies used to handle non-critical hardware shall be marked in accordance with the **MHE Used to Handle Non-Critical Hardware Identification** section of this Chapter.

3.6.3.3.4 Sling Assemblies Used to Handle Non-Critical Hardware Initial Test Requirements.

At a minimum, the following tests shall be performed on sling assemblies prior to their first operational use at the Ranges:

a. The proof load for single leg slings and endless slings shall be two times the vertical orientation rated capacity.

b. The proof load for multiple leg bridle slings will be applied to the individual legs and shall be two times the vertical orientation rated capacity of a single leg sling of the same size, grade, and construction of rope.

c. Chain falls shall be proof load tested to 125 percent of rated load (per ANSI B30.16).

d. Sling assemblies shall be visually inspected in accordance with ANSI inspection criteria.

3.6.3.3.5 Sling Assemblies Used To Handle Non-Critical Hardware Periodic Test Requirements. At a minimum, the following tests shall be performed on sling assemblies every four years. Unless otherwise agreed to by Range Safety, these tests shall also be performed after a sling assembly has been modified or repaired:

a. Sling assemblies shall be proof load tested to 200 percent of rated load.

b. Chain falls shall be proof load tested to 100 percent of rated load.

c. Sling assemblies shall be visually inspect-ed in accordance with ANSI inspection criteria.

3.6.3.3.6 Sling Assemblies Used to Handle Non-Critical Hardware Initial Data Requirements. At a minimum, the initial proof load test plan and results shall be maintained in the Sling Assembly Design and Initial Test Data Package.

3.6.3.3.7 Sling Assemblies Used to Handle Non-Critical Hardware Recurring Data Requirements. At a minimum, periodic proof load test and inspection results are required as part of the Sling Recurring Test Data File.

3.6.3.4 Handling Structures Used to Handle Non-Critical Hardware

3.6.3.4.1 Handling Structures Used to Handle Non-Critical Hardware Design Requirements.

a. All structural lifting beams shall meet the requirements of ANSI B30.20.

b. All handling structures shall be designed with a yield factor of safety of 3.

3.6.3.4.2 Handling Structures Used to Handle Non-Critical Hardware Marking Requirements. Handling structures used to handle critical hardware shall be marked in accordance with the **MHE Used to Handle Non-Critical Hardware Identification** section of this Chapter.

3.6.3.4.3 Handling Structures Used to Handle Non-Critical Hardware Initial Test Requirements. At a minimum, handling structures shall be proof load tested to 200 percent of rated load prior to their first operational use at the Ranges.

3.6.3.4.4 Handling Structures Used to Handle Non-Critical Hardware Periodic Test Requirements. At a minimum, handling structures shall be proof load tested to 200 percent of rated load every four years. Unless otherwise agreed to by Range Safety, this test shall also be performed after handling structure modification and/or repair.

3.6.3.4.5 Handling Structures Used to Handle Non-Critical Hardware Initial Data Requirements. At a minimum, initial proof load test plan and test results are required as part of the Handling Structure Design and Initial Test Data Package.

3.6.3.4.6 Handling Structures Used to Handle Non-Critical Hardware Recurring Data Requirements. At a minimum, periodic proof load test results are required as part of the Handling Structure Recurring Test Data File.

3.7 ACOUSTIC HAZARDS

3.7.1 Acoustic Design Standards

a. Systems shall be designed to ensure that personnel are not exposed to hazardous noise levels in accordance with MIL-STD-1472 and AFOSH 48-19. In all cases, noise shall be reduced to the lowest practical levels.

b. Where total protection is not possible through the design process, a hearing conservation program incorporating hearing protection and/or access controls shall be used.

c. Workspace noise shall be reduced to levels that permit necessary direct person-to-person and telephone communication.

d. Bioenvironmental Engineering shall evaluate noise levels and determine the hazard potential

3.7.2 Acoustic Data Requirements

The following data requirements shall be submitted as part of the MSPSP: (See Appendix 3A for guidance.)

a. The location of all sources generating noise levels that may result in hazardous noise exposure for personnel and the sound level (in decibels on the “A” scale [dBA]) for that noise

b. The anticipated operating schedules of these noise sources

c. Methods of protection for personnel who may be exposed to sound pressure levels above 85 dBA (8-hr time weighted average)

d. A copy of the Bioenvironmental Engineering approval stating the equipment and controls used are satisfactory

3.8 NON-IONIZING RADIATION SOURCES

3.8.1 Radio Frequency Emitters

3.8.1.1 Radio Frequency Emitter Design Standards

a. Radio frequency (RF) emitters shall be designed to ensure that personnel are not exposed to hazard levels in excess of those specified AFOSH 161-9.

b. Where total protection is not possible through the design process, clearance areas and access controls shall be established.

c. The RPO shall determine design requirements, evaluate RF levels, and determine the hazard potential for personnel.

3.8.1.2 Radio Frequency Emitter Design

3.8.1.2.1 Radio Frequency Emitter General Design Requirements.

a. RF emitters shall be designed and located to allow test and checkout without presenting a hazard to personnel, ordnance, or other electronic equipment.

b. Where necessary, interlocks, interrupts, or other safety devices shall be provided to protect operating personnel and exposed initiators during ground operations.

c. No ground based RF system shall be installed, erected, or relocated without site plan approval from Range Safety and the RPO. **NOTE:** This includes modifications to change transmitting characteristics.

d. Fail-safe systems shall be incorporated so that inadvertent operation of an RF emitting system is prevented.

3.8.1.2.2 Special Considerations for Electroexplosive Subsystem Exposure to RF Radiation

a. Electroexplosive subsystems shall not be exposed to RF radiation that is capable of firing the electroexplosive device (EED) by pin-to-pin bridgewire heating or pin-to-case arcing.

b. RF power at the EED shall not exceed 20 dB below the pin-to-pin direct current (DC) no-fire power of EED.

c. The siting of ground based RF emitters in proximity to electroexplosive subsystems shall be in accordance with Table 5-1, “Recommended EED Safe Separation Distances and Power Densities” in AFMAN 91-201 and DoD 6055.9-STD.

d. The effect of payload and launch vehicle system emitters on their own electroexplosive subsystem shall be evaluated by analysis or electromagnetic compatibility (EMC) testing.

3.8.1.3 RF Emitter Initial Test Requirements

a. All hazardous RF emitters shall have their RF hazard area verified by the RPO or a designated representative prior to the first operation and/or test.

b. Interlocks and other safety features shall be tested and verified by the Range User prior to coming to the Ranges.

1. Test plans shall be submitted to Range Safety for review and approval.

2. Test results shall be submitted to Range Safety.

3.8.1.4 RF Emitter Data Requirements

3.8.1.4.1 RF Site Plans. Site plans shall be submitted to Range Safety and the RPO for all ground based RF transmitters. The site plan shall include the following information:

a. Location of generating equipment

b. RF hazard areas

c. Description and use of nearby facilities and operating areas

3.8.1.4.2 RF Emitter Design and Test Data. The following RF emitter design and test data requirements shall be submitted as part of the MSPSP: (See Appendix 3A for guidance.)

a. Emitter peak and average power

b. Pulse widths

c. Pulse repetition frequencies

d. Pulse codes

e. Maximum rated duty cycle

f. Type and size of antenna

g. Antenna gain and illumination

h. Beam width and beam skew

i. Operating frequency (MHz)

j. Insertion loss between transmitter and antenna

k. Polarization of transmitted wave

l. An analysis of the RF hazard area with and without antenna hats/dummy load and results of any testing

m. A table that lists all of the RF emitters aboard a launch vehicle, payload, and ground support equipment and their hazard areas (distances)

n. A description of interlocks, inhibits, and other safety features that prevent inadvertent exposures

o. A copy of the RPO approved Radiation Protection Program RF User Request Authorization

p. A copy of the Range Safety and RPO approved site plan for all ground based RF emitters

3.8.2 Laser Systems

3.8.2.1 Laser System Design Standards

a. Laser systems shall be designed to ensure that personnel are not exposed to hazardous laser emissions in accordance with the requirements of AFOSH 161-10. Where total protection against exposure is not possible through the design process, clearance areas and access controls shall be established.

b. The RPO evaluates laser system design and operations and determines the hazard potential for personnel.

3.8.2.2 Laser System General Design Requirements

3.8.2.2.1 Radiation Hazards.

a. Interlocks, interrupts, or other safety devices shall be provided when necessary to protect personnel.

b. Fail-safe systems shall be incorporated so that inadvertent operation of the laser system is prevented.

c. Mechanical stops shall be provided to limit azimuth and elevation of tracking lasers.

d. Mechanical stops shall be used as backup for electrical inhibits to prevent laser radiation outside desired areas and to prevent mechanical damage to equipment.

e. Electrical inhibits shall be provided to inhibit laser radiation outside desired areas and to inhibit the azimuth and/or elevation drive motors before they reach the mechanical stops.

f. Emergency laser shutdown or shuttering capability shall be provided.

g. Emergency shutdown or shuttering shall be fail-safe or redundant.

3.8.2.2.2 Hazardous Materials. Hazardous materials used in laser systems shall meet the requirements of the **Hazardous Materials** section of this Chapter.

3.8.2.2.3 Cryogenic Systems Hazards. Cryogenic systems used in laser systems shall meet the requirements of the **Cryogenic Systems** sections of this Chapter.

3.8.2.2.4 Electrical Hazards. Electrical ground support equipment used for laser systems shall meet the requirements of the **Electrical and Electronic Equipment** section of this Chapter.

3.8.2.2.5 Mechanical Hazards.

a. Laser platforms shall comply with the requirements for mechanical ground support equipment used to handle critical hardware as described in the **Handling Structures Used to Handle Critical Hardware** section of this Chapter.

b. Moving mounts shall be stabilized to compensate for the motion of the vehicle.

c. Heating effects on unprotected laser platforms shall be considered when siting and setting elevation and azimuth stops.

3.8.2.3 Laser System Test Requirements

a. All hazardous laser systems and installations activated on the Ranges shall have their hazard area verified by the RPO or a designated representative prior to first operation and test.

b. Interlocks and other safety features shall be verified prior to coming to the Ranges.

c. Test Plans and test results shall be submitted to Range Safety for review and approval.

3.8.2.4 Laser System Data Requirements

The following laser system data requirements shall be submitted as part of the MSPSP: (See Appendix 3A for guidance.)

3.8.2.4.1 General Laser System Data Requirements.

a. A general description of the systems and its operation including how, where, why, and by whom the laser will be used. **NOTE:** The laser system also includes calibration equipment.

b. Drawings of the system that identify and show the location and operation of all components, interfaces, safety interlocks, and stops

c. For lasers that generate or use hazardous or corrosive materials, the data required for hazardous materials described in the **Hazardous Material Data Requirements** section of this Chapter

d. For lasers that use cryogenic fluids for cooling or operational enhancement, the data required for cryogenic systems and hazardous materials as described in the **Ground Support Pressure System Data Requirements** or the **Flight Hardware Pressure Systems Data Requirements** as applicable, and the **Hazardous Materials Data Requirements** sections of this Chapter

e. For laser systems using high voltages and/or high capacitance, the data required for electrical ground support equipment as described in the **Electrical and Electronics Equipment Data Requirements** section of this Chapter

3.8.2.4.2 Laser System Performance Data.

a. Type, class, nomenclature, manufacturer mo-del number, general identification, and other pertinent information *b*. General description of the test, pertinent drawing of the operation site, and associated equipment

c. Lasing material

d. Continuous Wave (CW) or pulse identification

e. Wave length

f. Bandwidth

g. Average power/energy per pulse/maximum output energy

h. Pulse duration and pulse rate

i. Beam width at 1/e point for both axes

j. A sketch of the beam pattern and location and energy density of hot spots and effects of weather and reflectivity

k. Beam divergence at 1/e point for both axes

l. Emergent beam diameter

m. Coolant

n. Amount of energy reflected back through the eyepiece or pointing device

o. Electrical voltage applied to the system

p. Any other pertinent laser parameter such as distribution of energy on beam and scanrate as determined by the Range User or Range Safety

q. Composition, color, and specularly or diffusely reflected surface characteristics of intended targets

r. Maximum incident energy on targets

s. Target characteristics including secondary hazards that may be affected by the laser, including fuels and other flammables, sensitive electronic components, flight termination systems, and others

t. Intended method such as binoculars or spotter scope for viewing the beam and/or its reflections

u. Safety devices such as interlocks, filters, shutters, and aiming devices

v. Azimuth and/or electrical and mechanical elevation stops

3.8.2.4.3 Hazard Evaluation Data. Analysis and supporting data outlining possible laser system failures for all phases of laser system uses shall be submitted. Such data includes the following:

a. All critical failure modes, failure mode effects, and failure probabilities including possible effects on secondary hazards. The results shall be included as part of a FMECA in accordance with MIL-STD-1543 and MIL-STD-1629.

b. Routine occupational hazard exposure that has been experienced in the past with the system or similar systems along with recommended methods for reducing or eliminating the hazards shall be included in an O&SHA in accordance with a jointly tailored System Safety Program (See Appendix 1B of this document).

3.8.2.4.4 Biophysiological Data.

a. Safe eye and skin distances based on permissible exposure limits

b. Safety clearance and hazard zones

c. Personal protective equipment (PPE) required for personnel remaining inside clearance zones

d. A copy of the RPO approved Radiation Protection Plan Laser Use Request Authorization

3.8.2.4.5 Test Plans and Test Results. Test plans and test results shall be submitted to Range Safety for review and approval.

3.9 RADIOACTIVE (IONIZING RADIATION) SOURCES

3.9.1 Radioactive Source Design Standards and Controls

3.9.1.1 Radioactive Sources Design Standards

a. Radioactive sources shall be designed to minimize the possibility of release of radioactive contamination.

b. Radioactive sources shall incorporate shielding in the design to ensure minimum exposure to personnel. Where total protection from radiation exposure by use of shielding is not feasible, access controls shall be employed.

c. Radioactive systems shall conform to the requirements specified in 10 CFR and 49 CFR

3.9.1.2 Additional ER Design Controls

Additional ER controls include compliance with 45 SWI 40-201 and approval by the RPO.

3.9.1.3 Additional WR Design Controls

Additional WR controls include the following:

a. Written approval from the 30 SW Radiation Safety Committee (RADSAFCOM) for processing and launch of radioactive sources. **NOTE**: 30 SW/SE is a voting member of the RADSAFCOM.

b. Range Users shall brief the RADSAFCOM on the hazards and procedures concerning the handling of radioactive sources and other information as required by AFI 91-110 30 SW1.

c. Range Users shall submit an approved environmental impact statement to the RADSAFCOM.

d. Radioactive sources shall be handled under the supervision of a designated Range User or the RPO named on the Nuclear Regulatory Commission (NRC) license, state license, or USAF permit. **NOTE:** Licensing and permitting requirements and procedures are specified in AFI 40-201 and AFI 91-110 30 SW1, and 30 SWI 40-201.

e. The final Safety Analysis Summary (SAS) and AFI 91-110 30 SW1 Radiation Protection Plan shall be submitted 120 days prior to source arrival on Vandenberg Air Force Base (VAFB).

f. Application for USAF permits shall be submitted to the RPO and shall include a copy of the NRC license.

g. The NRC license holder or Range User shall submit three copies of the NRC license with the USAF permit to Range Safety at least 30 calendar days prior to planned entry to the WR.

3.9.2 Radioactive Sources General Design

a. Radioactive sources shall be designed to minimize the potential for release of radioactive material during normal ground handling and launch operations and in credible launch abort and accident environments.

b. Radiation hazard warning signs and/or labels shall be fixed to the container or housing as directed by the RPO.

c. High voltage sources shall be evaluated to determine their capability of producing X-rays.

1. High voltage sources shall be properly shielded and shall use interlocks on cabinet doors to interrupt power when a door is open.

2. Control measures for flight systems shall be handled on a case-by-case basis.

3.9.3 Radioactive Sources Carried on Launch Vehicles and Payloads

In addition to the design requirements noted in the **Radioactive Sources Design Standards** section of this Chapter, radioactive materials carried on launch vehicles and payloads shall meet the following requirements:

3.9.3.1 Radioactive Sources Carried on Launch Vehicles and Payloads General Design Requirements

a. Radioactive materials carried aboard launch vehicles and payloads shall be compatible with and have no adverse safety effects on ordnance items, propellants, high pressure systems, critical structural components, or flight termination systems.

b. Radioactive materials carried aboard launch vehicles and payloads shall be designed so that they may be installed as late in the countdown as possible, particularly if personnel will be required to work within the system controlled radiation area (2 millirem per hr) while performing other tasks on the launch vehicle and/or payload.

3.9.3.2 Radioactive Sources Carried on Launch Vehicles and Payloads Test Requirements

a. For radioactive materials to be launched from the Ranges, adequate tests shall be performed to demonstrate the survival of the materials with minimal release of radioactive material within the launch vehicle, payload abort, and destruct environment. **NOTE:** Range Safety provides membership on the Interagency Nuclear Safety Review Panel (INSRP) on major sources to provide launch abort data and evaluation; therefore, some failure mode, breakup, and blast data may be obtained from the Program Office or Range Safety. In some situations, such as using a new launch vehicle, the data may not be available from the sources and shall be obtained by analysis and test following the requirements described in Chapter 2 of this document and through discussions with Range Safety.

b. Test Plans, Test Analyses, and Test Results

1. Test plans, analyses, and results shall be approved by Range Safety.

2. Range Users shall perform and document the results of radiation surveys of their radioactive sources prior to coming to the Ranges.

3. An initial radiation survey shall be performed by the RPO the first time the source is delivered to the Ranges.

4. Safeguards, such as interlocks and leak tests, shall be tested and verified by the Range User prior to bringing a radiation source to the Ranges.

3.9.3.3 Radioactive Sources Carried on Launch Vehicles and Payloads Launch Approval Requirements

a. Range Users contemplating launch of any radioactive source shall comply with AFI 91-110 and the National Aeronautics and Space Council document *Nuclear Safety Review and Approval Procedure for Minor Radioactive Sources in Space Operations*.

b. At the WR, Range Users shall also comply with AFI 91-110 30 SW1 and 30 SWI 40-201.

c. Non-Air Force users may use their own agencies' equivalent document if it meets the requirements of AFI 91-110 and the National Aeronautics and Space Council document *Nuclear Safety Review and Approval Procedure for Minor Radioactive Sources in Space Operations*.

d. Certification of compliance with an equivalent government agency safety review and launch approval process is required for all non-Air Force Range Users.

e. All Range Users proposing to use major radioactive sources shall comply with Presidential Directive/National Security Council (NSC) 25, dated 14 December 1977, *Scientific or Technological Experiments with possible Large-Scale Adverse Environmental Effects and Launch of Nuclear Systems into Space*.

3.9.3.4 Radioactive Sources Launch Approval Data Requirements

3.9.3.4.1 Letter of Certification. Range Users shall provide a letter of certification to the Range Commander with a copy provided to Range Safety stating that they have complied with the Office of Science Technology Policy NASC letter, AFI 91-110, or the Presidential Directive/NCS-25 as appropriate.

3.9.3.4.2 MSPSP Data. The following data shall be submitted to Range Safety as part of the MSPSP:

a. The final SAS as required by AFI 91-110 or equivalent document if non-Air Force Range User. **NOTE:** The SAS shall be referenced in the MSPSP and submitted as an accompanying document.

1. Status reports on the SAS approval and copy of the Technical Nuclear Safety Evaluation (TNSE)

2. Verification of approval for launch by separate correspondence in accordance with the requirements of AFI 91-110 or the equivalent

b. Manufacturer of the source

c. Date of source preparation

d. Source identification number

e. Cross-sectional sketch showing dimensions of the source

f. Source container or holder construction material

g. Physical source form such as powder or plate

h. Chemical source form such as metal or oxide

i. Strength in curies

j. Type of protective cover material over the source

k. Date and result of last wipe test

l. Method of sealing against leakage

m. Radionuclide solubility in sea water

n. Description, including diagrams, showing exact placement of source in vehicle or payload

o. A brief description of intended use

p. Radiation levels in millirem per hour for all modes of operation and all radiation container surfaces accessible to personnel

q. Description of potential accidents that would cause release of radioactive material including potential personnel exposure and ground contamination

r. A summary of the possible consequences of a release of radioactive material at the Ranges including the maximum credible release and recommendations for methods to reduce or eliminate the resulting hazards

s. Description of recovery plans for land and sea launch abort scenarios

t. Location and name of responsible organization and licensed individual assigned to supervise handling of this material

u. Detailed nuclear system design

v. Normal and potentially abnormal environments and failure modes that can affect the processing, launch, and flight of a nuclear system

w. The predicted responses of the nuclear system to processing, launch, and flight environments and failures

x. The predicted resulting nuclear risk

y. Ground support equipment design data as re-quired by the appropriate sections of this document

z. Detailed ground processing flow

aa. The final intended disposition of the radioactive source

ab. A copy of the RPO approved 45 SWI 40-201 Radiation Protection Program (ER only)

ac. A copy of the AFI 91-110 30 SW1 Radiation Protection Plan (WR only)

3.9.4 Radiation Producing Equipment and Devices Data Requirements

The MSPSP shall identify all flight and ground radiation producing devices. The following information shall be provided:

a. Manufacturer and model number

b. A description of the system and its operation

c. A description of the interlocks, inhibits and other safety features

d. If installed on a flight system, a diagram show-ing the location

e. Radiation levels in millirems per hour for all modes of operation and all radiation container surfaces accessible to personnel. **NOTE**: Levels with doors and access panels removed shall be included.

f. A copy of the RPO approved 45 SWI 40-201 Radiation Protection Program Radiation Use Request Authorization to use these sources during ground processing.

g. A copy of the AFI 91-110 30 SW1 Radiation Protection Plan (WR only)

3.10 HAZARDOUS MATERIALS

3.10.1 Hazardous Materials Selection Criteria

3.10.1.1 Hazardous Materials Flammability and Combustibility

a. The least flammable liquid or material shall be used where feasible.

b. Materials that will not burn readily upon ignition shall be used.

3.10.1.2 Hazardous Materials Toxicity

NOTE: National Aeronautics and Space Administration (NASA), Kennedy Space Center (KSC), and Range Safety have data on materials that have already been tested.

a. The least toxic liquid or material shall be used where feasible.

b. Materials that will not give off a toxic gas if ignited shall be used.

3.10.1.3 Hazardous Materials Compatibility

a. Materials, including leakage, shall not come in contact with a non-compatible material that can cause a hazard.

b. Compatibility shall be determined on a case-by-case basis.

3.10.1.4 Hazardous Materials Electrostatic Build-Up

Hazardous materials shall not retain a static charge that presents an ignition source to ordnance or propellants or a shock hazard to personnel.

3.10.2 Hazardous Materials Test Requirements

3.10.2.1 Plastic Materials Test Requirements

a. Plastic materials that may pose a hazard because of compatibility, flammability, or electrostatic build-up shall be tested in accordance with the requirements described in KSC Material Testing Laboratory report Material Testing Bulletin MTB-402-85.

b. The results of the test shall be submitted to Range Safety for review and approval based on use.

3.10.2.2 Other Hazardous Material Test Requirements

a. Range Safety may require the testing of materials whose hazardous properties are not well defined.

b. Toxicity, reactivity, compatibility, flammability and/or combustibility testing requirements shall be determined by Range Safety on a case-by-case basis.

3.10.3 Hazardous Materials Environmental Requirements

a. The use of ozone depleting chemicals and hazardous materials that result in the generation of reg-ulated hazardous waste shall be minimized to the greatest extent possible in accordance with federal and state regulations.

b. Hazardous waste management and disposal procedures and plans shall be reviewed and approved by Environmental Planning.

c. Range User business plans will comply with the Base Hazardous Materials (HAZMAT) Plan.

3.10.4 Hazardous Material Data Requirements

The following information shall be included in the MSPSP:

a. A list of all hazardous materials on the flight system and those used in ground processing

b. A description of how and under what conditions each of these materials and liquids is used and in what quantity

c. A description of flammability and, if applicable, explosive characteristics including test results provided or referenced

d. A description of toxicity including Threshold Limit Value (TLV) and other exposure limits, if available *e*. A description of compatibility including a list of all materials that may come in contact with a hazardous liquid or vapor with test results provided or referenced

f. A description of electrostatic characteristics with test results provided or referenced including bleed-off capability of the as-used configuration

g. A description of PPE to be used with the hazardous material and liquid; including type, make, and location

h. A summary of decontamination, neutralization, and disposal procedures

i. A Material Safety Data Sheet (MSDS) for each hazardous material and liquid on flight hardware or used in ground processing. **NOTE:** The MSDS shall be available for review at each location in which the material is stored or used.

j. Description of any detection equipment, location, and proposed use

k. Additional data required for plastic material includes:

1. Identification of the cleaning methods to be used to maintain surface cleanliness and conductivity, if applicable

2. Identification of the minimum acceptable voltage accumulation levels for the plastic materials or operations

3. Identification of the method for ensuring conductivity between adjoining pieces of the plastic materials

4. Assessment of the environmental effects on plastic materials such as humidity, ultraviolet light, and temperature that could cause degradation of conductivity, flammability, or electrostatic properties

3.10.5 Process Safety Management

a. Range Users shall comply with 29 CFR 1910.119 and AFOSH 91-119 for Process Safety Management.

b. Additional ER Requirements: Range Users shall comply with the 45 SW Process Management Implementation Plan. **NOTE:** The point of contact is 45 SW/SES.

c. Additional WR Requirements: Range Users shall comply with 30 SW Plan 91-119. **NOTE:** The point of contact is 30 SW/SES.

3.11 GROUND SUPPORT PRESSURE SYSTEMS

3.11.1 Ground Support Pressure Systems Design Requirements

This section establishes minimum design, fabrication, installation, testing, inspection, recertification, and data requirements for fixed, portable, or mobile ground support hazardous pressure systems. Ground support systems include aerospace ground equipment (AGE), ground support equipment (GSE), missile support systems, real property installed equipment (RPIE), and industrial property.

3.11.1.1 Definition of Ground Support Hazardous Pressure Systems

Ground support hazardous pressure systems are defined as follows: (1) systems used to store and transfer hazardous fluids such as cryogens, flammables, combustibles, and hypergols; (2) systems with operating pressures that exceed 250 psig; (3) systems with stored energy levels exceeding 14,240 ft lb; (4) systems that are identified by Range Safety as safety critical

3.11.1.2 Non-Hazardous Pressure System Design

Non-hazardous pressure systems shall be designed in accordance with accepted national industry standards such as NFPA, UL, API, and FDEP.

3.11.1.3 Ground Support Vacuum System Design

a. Vacuum systems should be designed in accordance with T.O. 00-25-223.

b. Pressure systems used to store and transfer fuels such as kerosene, RP-1, and heating oils are not generally considered hazardous when designed and operated in accordance with the following requirements:

1. Pressure shall not exceed 15 psig

2. The system shall be designed, maintained and operated in accordance with API 620 and applicable EPA and OSHA requirements,

3. Vessels/tanks and systems shall be inventoried and records maintained in the Eastern Range Pressure System Database Management Program

3.11.1.4 Compliance Documents

Federal regulations such as those published by the Department of Transportation (DOT), the Environmental Protection Agency (EPA), and the Occupational Safety and Health Administration (OSHA) and industry standards are specified as compliance documents throughout this section. When there is a conflict between federal regulations, industry standards, or other requirements in this section, the more stringent requirement shall be used unless otherwise agreed to by Range Safety.

3.11.1.5 Ground Support Pressure System Repairs and Modifications

Repairs and/or modifications to tankage, piping, and other components shall be performed to the same standards, codes, and requirements as for new systems and components.

3.11.1.6 Ground Support Pressure System Operation

The requirements for operating hazardous pressure systems found in Chapter 6 of this document shall be taken into consideration in the design and testing of these systems.

3.11.1.7 Ground Support Pressure System Fault Tolerance

a. Ground support hazardous pressure systems shall be designed to ensure that no single failure (component fails to function or human operator error) can result in serious injury and/or loss of life.

b. Single-fault tolerant systems shall have at least two, Range Safety approved, independent and verifiable inhibits in place during all periods when the potential for serious injury and/or death exists. **NOTE:** Structural failure of tubing, piping, or pressure vessels are not to be considered single failures.

c. Range Safety may require that a pressure system be dual-fault tolerant if the failure of two components could result in a catastrophe (multiple injuries or deaths).

3.11.1.8 Ground Support Pressure System Hazard Analysis

a. As applicable, a hazard analysis, shall be performed on all hazardous systems hardware and software in accordance with a jointly tailored System Safety Program (Appendix IB). Tailoring shall be accomplished by Range Safety and the Range User.

b. At a minimum, the hazardous analysis shall include the analysis requirements in 29 CFR 1910.119 and AFI 32-4002 for toxic, reactive, flammable, and explosive fluids.

3.11.1.9 Ground Support Pressure System Safety Factor

a. Safety factor for pressure systems is defined as the ratio of design burst pressure over the maximum allowable working pressure or design pressure, whichever is greater. The safety factor can also be expressed as the ratio of tensile strength over the maximum allowable stress for the material.

b. American Society of Mechanical Engineers (ASME) or DOT codes are specified as compliance documents for various components such as pressure vessels and piping throughout this section. Acceptable safety factors have already been incorporated into the specified code. If an ASME or DOT code is not specified in this section as a compliance document for a component (applicable code does not exist), the minimum safety factor for the component shall be 4.

3.11.1.10 Ground Support Pressure System Material Selection and Compatibility

a. Materials shall be compatible throughout their intended service life with the service fluids and the materials such as supports, anchors, and clamps used in construction and installation of tankage, piping, and components as well as nonmetallic items such as gaskets, seals, packing, seats, and lubricants.

b. At a minimum, material compatibility should be determined in regard to the following criteria: permeability, flammability, ignition and combustion, functional and material degradation, contamination, toxicity, pressure and temperature extremes, shock, oxidation, and corrosion.

c. Brittle materials shall not be used for pressure system components. The nil-ductility transition temperature of materials shall be below the service temperature. **NOTE:** Reliable sources such as MIL-HDBK-5, MIL-HDBK-17, American Society for Testing Materials (ASTM) Standards, AFML/-AFFOL Damage Tolerant Design Handbook shall be used to verify material is not crack sensitive.

d. Materials that could come in contact with fluid from a ruptured or leaky tank, pipe, or other components that store or transfer hazardous fluids shall be compatible with the fluid so that it does not create a flammable, combustible, or toxic hazard.

e. Compatible materials selection shall be obtained from one of the following sources:

1. T.O. 00-25-223

2. Chemical Propulsion Information Agency 394 (CPIA 394)

3. Marshall Space Flight Center Handbook 527 (MSFC-HDBK-527)

f. Compatibility Testing

1. Materials shall be tested for compatibility if data does not exist.

2. If compatibility testing is performed, the test plan shall be submitted to Range Safety for review and approval.

g. Compatibility Analysis. A compatibility analysis containing the following information shall be prepared:

1. List of all materials used in system

2. Service fluid in contact with each material

3. Materials that may come in contact with leaking fluid

4. Source document or test results showing material compatibility in regard to permeability, flammability, ignition and combustion, functional and material degradation, contamination, toxicity, pressure and temperature extremes, shock, oxidation, and corrosion

3.11.1.11 Ground Support Pressure System Corrosion Control

NOTE: The atmosphere at the ER contains a high salt content that is readily deposited on exposed surfaces. Combined with acidic solid rocket booster effluent and substantial rainfall, steady winds, low land elevation, and generally high humidity and temperatures, this results in an ideal environment for extensive metal corrosion. These conditions induce both electrolytic action and chemical reactions depending on the metals involved and how they are used. The atmosphere at Vandenberg Air Force Base (VAFB) is similar to Cape Canaveral Air Station CCAS except that fog is the predominant moisture source. Although corrosion control is primarily the responsibility of the maintainer of the equipment, the designer is responsible for providing hardware that will not present safety problems caused by corrosion. KSC-STD-0001 or National Association of Corrosion Engineers (NACE) RP-2-85 shall be used as guidance for corrosion control.

3.11.1.11.1 Determining Hazardous Pressure System Location.

a. The location of hazardous pressure systems at the Ranges shall be identified including the types of corrosion that may be encountered (oxidation and reduction, galvanic, corrosion fatigue, stress corrosion cracking, and corrosive atmosphere).

b. Once these environments have been identified, the appropriate corrosion protection shall be provided.

3.11.1.11.2 Corrosion Protection Coatings.

Corrosion protection coatings for fixed outdoor pressure systems including supports, anchors, and clamps are as follows: **NOTE:** Alternate coatings that provide equal or better protection may be used.

a. Carbon steel surfaces should be protected from atmospheric corrosion through the application of zinc coatings (inorganic zinc coating and/or hot-dip galvanizing).

b. Stainless steel surfaces on piping and vessels that receive rocket engine exhaust impingement or acid deposits from solid rocket motor exhaust should be painted with a nitrile rubber-based aluminum pigmented coating.

c. Stainless steel surfaces on piping and vessels used in hypergolic propellant systems shall be painted with a nitrile rubber-based aluminum pigmented coating.

d. Underground vessels and piping should be coated with coal tar epoxy.

e. All hypergolic underground systems shall be protected against corrosion by cathodic protection. Cathodic protection systems (sacrificial or DC power) shall be designed so that a periodic check of the system can be obtained.

f. Dissimilar metals shall be protected against galvanic corrosion through mutual isolation.

3.11.1.11.3 Use of 17-4PH Stainless Steel.

a. The use of 17-4PH stainless steel shall be avoided where possible due to its susceptibility to stress corrosion cracking at low heat treatment levels.

b. Any 17-4PH stainless steel specified shall require heat treatment to condition H1025 or higher.

3.11.1.11.4 Avoidance of Type 303 Stainless Steel. Where 300-series stainless steels are specified, type 303 shall be avoided wherever possible due to susceptibility to stress corrosion cracking.

3.11.1.12 Ground Support Pressure System Contamination Control

Adequate levels of contamination control shall be established by relating the cleanliness requirements to the actual needs and nature of the system and components. KSC-C-123 or T.O. 42C-11 shall be used as guidance.

a. Materials and fluids used in the design shall be selected to reduce internally generated contamination caused by rate of wear, friction, and fluid decomposition.

b. Systems shall have acceptable contamination tolerance levels. **NOTE**: The tolerance level of the system and/or components shall be based on considerations of the overall functional requirements and service life.

c. Components and systems shall be protected from contaminants by adequate filtration, sealed modules, clean fluids and clean environment during assembly, storage, installation and use.

d. The system shall be designed or marked to prevent incorrect installation of filters.

e. Accessibility shall be provided for inspection and testing of systems and components and for removal of contaminants and filters by allowing means of disassembly for cleaning, drainage, and post-assembly cleaning and maintenance.

f. The system shall be designed to verify through sampling that the lines and components are clean after flushing and purging of the system.

g. Each component or section of a system shall be cleaned to the appropriate level prior to installation. Immediately following cleaning, all components or sections of a system shall be protected to prevent contamination.

h. Filters shall be installed immediately upstream of all interfaces where control of particulate matter is critical and at other appropriate points as required to control particulate migration. **NOTE:** Filter design shall permit easy servicing and ready accessibility.

i. Equipment designed to be cleaned or recleaned in place without significant disassembly shall be provided with high point bleeds and low point drains to facilitate introduction and removal of cleaning fluid.

3.11.1.13 Ground Support Pressure System Service Life

All hazardous pressure system components shall operate safely and reliably during their intended period of service (service life). Components shall not fail at operating conditions in a time period that is 4 times the service life of the components. Minimum service life requirements are as follows:

a. Permanently installed pressure vessels shall be designed to have a service life of at least 20 years.

b. Other components shall be designed to have a service life of not less than 5000 cycles. Normal preventive maintenance or calibration may be performed to maintain the service life.

3.11.1.14 Inservice Operating, Maintenance, and Inspection Plan

The Range User responsible for the design of hazardous pressure systems shall prepare an inservice operating, maintenance, and inspection plan. This plan will be referred to as the Inservice Inspection (ISI) Plan. **NOTE**: Guidance for preparing the ISI Plan can be found in ESMC-TR-88-01, *A Guide for Recertification of Ground Based Pressure Vessels and Liquid Holding Tanks*.

a. The ISI Plan shall address and provide the following:

1. Credible failure mechanisms that may cause service related failures of the system during its service life shall be analyzed.

2. Methods such as "eliminated," "controlled by design," "controlled by procedure," or "controlled by corrosion protection" used to eliminate and control these failure mechanisms shall be identified. **NOTE**: Failure mechanisms to be evaluated include corrosion, stress, fatigue, creep, design fabrication, installation, operation, and maintenance deficiencies.

3. Using the results of the above failure mechanism analysis, the following minimum requirements for an operating, maintenance, and inspection plan shall be defined:

(a) Operating plans shall address operating constraints such as maximum pressure, maximum allowable working pressure (MAWP), maximum operating pressure (MOP), minimum and maximum temperature, vibration, and maximum cycles.

(b) Maintenance plans shall address corrosion protection, maintenance schedule, soft-good replacement program, refurbishment, calibration, and other maintenance requirements.

(c) Inspection plans shall identify the type and frequency of inspections such as visual, surface and volumetric, NDE required for each vessel and system to detect the types of failure mechanisms identified in *(1)* above.

b. Hazardous pressure systems shall be maintained and periodically inspected in accordance with the ISI Plan.

c. Unacceptable findings from the performance of periodic inspections shall be resolved with Range Safety participation.

3.11.1.15 Physical Arrangement and Human Factors Requirements for Ground Support Pressure Systems

Pressure systems shall be designed to provide adequate accessibility, clearance, and operating safety.

3.11.1.15.1 Accessibility.

a. Components shall be located to provide ease of maintenance and calibration.

b. Access ladders and platforms shall be provided for components that cannot be located in normal work areas.

c. Hypergolic system design shall take into consideration the limitations imposed on individuals dressed in Self-Contained Atmospheric Protective Ensemble (SCAPE) suits or Propellant Handlers Ensemble (PHE).

d. Pressure systems shall be designed so that removal and replacement of tubing can be accomplished with minimal removal of other system components.

e. Pressure lines shall not be installed inside conduit, large pipe, or tubing for protective support. *EXCEPTION: Lines may be enclosed in protective conduit, pipes, or tubing when routed under roadways, obstructions, and through thick walls.*

f. All piping shall be located so that it is accessible for maintenance.

g. Systems shall be designed with accessibility to perform end-to-end static ground system checks.

h. Where possible, pipes containing hazardous liquids shall be routed in a gradual, direct, downgrade angle to prevent the accumulation of trapped liquid fluids and allow draining of the lines.

i. Where possible, pipes carrying hazardous liquids shall be mounted so that the liquid will not be trapped in internal cavities when it is drained.

3.11.1.15.2 Clearance.

a. Tubing shall be located and protected so that damage will not occur due to being stepped on, used as handholds, or by manipulation of tools during maintenance.

b. Pressure lines shall clear all structures, components, and other lines by not less than 1/4 in. under the most adverse conditions of service to ensure that abrasive chafing does not occur.

c. Piping, tubing, and other components shall be routed or located to provide protection from other operational hazards, including moveable equipment. **NOTE:** Where such exposure is unavoidable, safeguards that minimize the effects of such exposure shall be incorporated in the design.

d. Where feasible, high pressure lines and components shall be protected from damage due to leak-age, servicing, or other operational hazards created by other systems.

e. All welded pipe fabricated in place shall be installed with a minimum 6-in. clearance from building structures.

f. The minimum spacing between fuel and oxidizer piping shall be 24-in. in any direction.

g. Pipes containing liquids shall not be attached or secured to electrical lines or conduit.

h. A minimum spacing of 2 in. shall be maintained between an electrical conduit and a pressure line.

i. Vent outlets shall be located far enough away from incompatible propellant systems and incompatible materials to ensure that no contact is made during vent operations.

j. System connections for incompatible propellants shall be keyed, sized, or located so that it is physically impossible to interconnect them. **NOTE:** Unless otherwise agreed to by Range Safety, breathing air quick disconnects (QDs) shall use 3/8 in. Hansen QDs (part numbers LL3-K21 (male) and LL-H21 (female). In addition, the 3/8-in. Hansen QD will not be used for any other type system.

k. Redundant legs (i.e., branches) of a safety pressure system shall be physically separated and protected so that a single event (such as damage, fire, or an explosion) will not cause both redundant legs to fail.

l. Components shall be located and lines routed so that a leak or rupture will not cause ignition.

m. Safety relief valves and burst diaphragms shall be located so that their discharge is directed away from personnel or safety critical equipment to prevent injury to personnel or damage to safety critical equipment. **NOTE 1:** If this requirement cannot be met, safety valves and burst diaphragms shall be equipped with deflection devices. **NOTE 2:** Consideration shall be given to minimizing the noise hazard of high pressure venting.

n. Vent lines for flammable and combustible vapors shall be extended away from work areas to prevent accidental ignition of vapors and/or injury to personnel.

o. Pipe routing shall not block personnel egress routes.

3.11.1.15.3 Human Factors.

a. System components such as a hand regulator and gauge that are closely related shall be arranged to allow operation and surveillance from a common point.

b. Remotely controlled systems shall have emergency manual safing controls located inside and outside of the hazard area.

c. Pressure systems shall be designed so that the operator is not required to leave the operating control station to monitor the hazard level of that system.

d. For remotely controlled valves, positive indication of actual valve position shall be displayed at the control station. **NOTE:** Indication of valve stem position or flow measurement is an acceptable indication. Indication of a remote command being initiated is not a positive indication of valve position.

e. All piping shall be located so that it is not hazardous to working personnel.

f. All calibration adjustments shall be designed so that the setting, position, or adjustment cannot be inadvertently altered.

g. All valves that shall remain in a CLOSED or OPEN position during system operation shall be protected against inadvertent actuation by mechanical stops, lock wires, or access control.

h. Valves carrying hazardous liquids shall not be located overhead in the area of an operating station.

i. Manually operated liquid valves shall be located to permit operation from the side or above to prevent spillage of service fluid on the operator due to leak or failure of the valve seals.

j. MIL-STD-1472 or equivalent should be used as guidance in designing pressure system operating consoles.

3.11.1.16 Identification and Marking of Components and Control Panels/Consoles

3.11.1.16.1 Hazardous Pressure Systems Component Identification. All hazardous pressure system components shall be identified as to function, content, applicable hazard, and, if applicable, direction of flow. Minimum identification and marking requirements are as follows:

a. Fixed Pressure Vessels

1. Fixed pressure vessels shall be code stamp-ed in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or Division 2.

2. The maximum pressure at which fixed pressure vessels will be normally operated and the name of the working fluid shall be painted in a conspicuous location on the vessel facing the roadway approach, if possible. **NOTE**: This additional labeling shall be legible at a distance of 50 ft.

b. Portable and mobile pressure vessels shall be marked in accordance with the applicable DOT specifications.

c. Individual lengths or fabricated assemblies of pipe and tubing shall be identified with pipe and/or tube size, schedule number and wall thickness, test pressure, and the date of hydrostatic and/or pneumatic test. Identification data shall be fixed to the pipe and tubing by means of an attached stainless steel tag.

d. Fixed ground support piping and tubing runs external to regulation and control panels and consoles shall be identified in accordance with MIL-STD-1247 or equivalent.

e. All RPIE shall be identified in accordance with MIL-STD-101 or equivalent.

f. Shutoff and metering valves, regulators, gauges, and filters shall have the following information permanently attached to the body by stamping, engraving, tagging, or other means:

1. Manufacturer and/or contractor name

2. Manufacturer part number

3. Applicable design pressure rating

4. Service media

5. Month and year of most recent calibration for gauges and transducers

6. Flow direction arrow, if applicable

7. System reference designation for the component, such as CV1, CV2

g. Flex hoses shall be provided with an identification tag that is permanently and legibly marked with the following information:

1. Manufacturer name

2. Manufacturer and/or contractor part number

3. Hose size

4. MAWP or manufacturer rated working pressure

5. Service media

6. Month and year of most recent hydrostatic test and test pressure

7. System reference designation for the hose such as FH1, FH2

h. Pressure Relief Devices

1. Pressure relief devices shall be marked in accordance with ASME Code Section VIII, Division 1, Paragraphs UG-129, UG-130, UG-131, and UG-132 as applicable.

2. An identification tag that is permanently and legibly marked with the month and year of the most recent set pressure calibration shall be attached to the relief valve.

3.11.1.16.2 Pressure Vessels, Valves, and Other Component Identification. The marking and identification of pressure vessels, valves, and other components shall be accomplished by some means that will not cause “stress concentration” or otherwise reduce the integrity of the system.

3.11.1.16.3 Manual Pressure System Regulation and Control Panel and Console Identification. All manual pressure system regulation and control panels and consoles shall be clearly marked with a flow schematic, operating parameters, and component identification.

3.11.1.17 Ground Support Pressure System Supports, Anchors, Clamps, and Other Restraints

a. All piping supports, anchors, hangers, and other restraints shall conform to the requirements of American National Standards Institute (ANSI/ ASME) B31.3, paragraph 321.

b. Hazardous pressure system piping shall be installed with sufficient flexibility to prevent static or dynamic flow-induced loads and thermal expansion or contraction from causing excessive stresses to be induced in the system, excessive bending moments at joints, or undesirable forces or moments at points of connection to equipment or at anchorage or guide points.

c. Line Restraints

1. Where line restraint is required, anchors, guides, pivots or restraints shall be fabricated or purchased and assembled in such a form as to secure the desired points of piping in relatively fixed positions.

2. Line restraints shall permit the line to expand and contract freely in opposite directions away from the anchored or guided point.

3. Line restraints shall be designed to withstand the thrust, torsional forces, and load conditions of operation.

4. Line restraints shall contain the line in case of line failure.

5. The support shall be capable of withstanding no less than two times the available force as a result of thrust generated from component failure under pressure.

d. All relief valves and attached vent piping shall be designed to withstand any thrust caused by venting fluids.

e. All rigid tubing assemblies shall be supported by rigid structures using cushioned steel clamps or suitable multiple-tube block-type clamps.

f. Tubing supports within consoles or modules shall be spaced according to the maximum spacing listed below:

Nominal Tubing Diameter (in.)	Maximum Distance Between Tubing Support (in.)
1/8 through 3/8	18
1/2 through 3/4	25
1 and over	30

g. Tubing supports between consoles and modules shall be spaced according to the maximum spacing listed below:

Nominal Tubing Diameter (in.)	Maximum Distance Between Tubing Supports (ft)
1/8 through 3/8	4
1/2 through 7/8	6
1 through 2	9

h. Components within a system shall be supported by a firm structure and not the connecting tubing or piping unless it can be shown by analysis that the tubing or piping can safely support the component with a safety factor of 3 against yield.

3.11.1.18 Ground Support Pressure System Bonding and Grounding

3.11.1.18.1 Hazardous Pressure System Bond-ing and Grounding. All hazardous pressure systems shall be properly bonded and grounded to provide the following. **NOTE:** National Fire Protection Association (NFPA) 77 and KSC-STD-E-0012 shall be used as guidance.

a. A low-impedance path to earth for electrical currents resulting from lightning discharges or electrical power system faults to minimize abnormal voltage rises that might injure personnel or damage equipment

b. A discharge path between distribution piping and tubing and earth to prevent the buildup of static electricity

3.11.1.18.2 Combustible and Flammable Pressure System Piping and Tubing. Minimum metal pipe and tube bonding requirements for combustible and flammable pressure systems are as follows:

a. Piping and tubing shall be bonded to ground at the end termination and at intervals of not more than 100 ft.

b. Systems located outdoors shall have brazed or welded bonds. *EXCEPTION: Stainless steel clamps may be used to bond stainless steel pipe to ground if brazing or welding would cause dissimilar metal concerns.*

c. Flanged joints are acceptable if the flanges are stainless steel or the flanged areas in contact with the bolt heads and washers are clean and bright. In addition, the bolts and nuts shall be equipped with serrated or spring washers to maintain tightness.

d. Tubing sections joined with fittings that seat metal-to-metal are considered adequately bonded.

3.11.1.18.3 Non-Flammable and Non-Combustible Pressure Piping and Tubing. Non-flammable and non-combustible pressure system piping and tubing shall be bonded to ground at the end terminations and at intervals of not more than 300 ft.

3.11.1.18.4 Fixed Facility Transfer Apron Bonding and Grounding Station. All fixed facility transfer apron areas shall be equipped with a bonding and grounding station for use with associated mobile equipment.

3.11.1.18.5 Use of Copper, Bronze, and Other Alloys in Hydrazine Areas.

a. Copper, bronze, or other alloys that might form copper oxides should not be used in hydrazine areas. If used, they shall be positively protected by distance, sealing in a compatible material, or use of a splash guard.

b. The use of interconnecting dissimilar ground metals that could lead to increased resistance due to galvanic corrosion over a relatively short time period shall be avoided.

3.11.1.18.6 Bonding and Grounding Resistance Values. The following resistance values are the maximum desired to achieve the intended bonding and grounding requirements:

a. Any single joint measurement shall exhibit a DC resistance of 10 milliohms or less.

b. DC resistance from any point in the piping and tubing system to the nearest earth electrode ground plate shall be 100 milliohms or less.

3.11.2 Ground Support Pneumatic Systems

This section contains minimum safety requirements for all fixed, portable, and mobile equipment used to handle gaseous nitrogen, helium, oxygen, hydrogen, breathing air, and any other gas or gas mixtures designated by Range Safety.

3.11.2.1 Compressed Air Systems

Compressed air systems operating at 250 lb/in^2 or less shall be designed in accordance with accepted industry standards such as OSHA 1910.169 and ANSI/ASME B19.

3.11.2.2 Ground Support Pressure Vessels

3.11.2.2.1 Permanently Installed Pressure Vessels.

a. All permanently installed pressure vessels shall be designed, constructed, tested, certified, and code stamped in accordance with the ASME Code, Section VIII, Division 1 or Division 2.

b. All ASME code stamped vessels shall be registered with the National Board of Boiler and Pressure Vessel inspectors.

c. The following additional design, fabrication, and inspection requirements shall also be met:

1. Pressure vessels shall be designed with an opening for inspection purposes.

2. Pressure retaining welds including all shell, head nozzle, and nozzle to head or shell welds shall be inspected using volumetric and surface NDE techniques.

3. At a minimum, all attachment welds such as supports, lugs, pads, and nameplates shall be inspected using surface NDE techniques.

4. Welded attachments such as stiffening rings or supports shall be welded with a continuous weld bead.

5. Welded and bolted attachments such as piping, gussets, ladders, and platforms to the pressure vessel shall be minimized.

6. External and internal surfaces of vessels shall be free of crevices and other areas that can trap moisture or contaminants.

7. All attachments shall be positioned so that no attachment weld will overlap any category A or B weld as defined by ASME Code, Section VIII, Division 1 or Division 2.

8. SA514, SA517, or other alloys with substantially the same properties as T-1 steel shall not be used for pressure vessels that are fabricated by welding.

9. All fixed pressure vessels exposed to the atmosphere and winds shall be designed with a minimum 2 psig external pressure load.

3.11.2.2.2 Portable and Mobile Pressure Vessels.

a. Portable and mobile pressure vessels used for transportation of hazardous materials shall be designed, fabricated, inspected, and tested in accordance with 49 CFR.

b. A copy of any DOT approved exemptions shall be provided to Range Safety.

3.11.2.2.3 Permanently Installed Portable and Mobile Pressure Vessels.

a. Pressure vessels designed and fabricated according to DOT codes are not normally specified for permanent installation in high pressure systems.

b. If such vessels are installed on a permanent basis, the installation shall meet ASME design requirements or be installed to permit easy access to hydrostat the vessel periodically in compliance with DOT regulations.

c. If DOT vessels are used in portable GSE, maintenance and operating procedures for periodic hydrostatic tests shall be in accordance with DOT regulations.

3.11.2.3 Ground Support Pneumatic System Piping

All piping installations shall be designed, as a minimum, in accordance with ANSI/ASME B31.3 in addition to the following:

a. Recommended pipe material is seamless cold-drawn, type 304L or type 316L stainless steel in accordance with ASTM A312 and ANSI/ASME B36.10M.

b. Weld fittings such as tees, crosses, elbows, and reducers should be of the butt weld type in accordance with ANSI B16.9 and be constructed of ASTM A403, grade WP-316L or WP-304L material.

c. Mechanical joints should be made of ASTM A182 F316 butt weld hubs, ASTM A182 F304 clamp assemblies, and type 17-4PH teflon-coated seal rings. **NOTE**: Where system design dictates the use of industrial flanged type mechanical joints, they shall be in accordance with ANSI B16.5.

d. Threaded National Pipe Thread (NPT) connectors shall not be used in hazardous pressure system piping unless specifically approved by Range Safety.

e. Socket welded flanges shall not be used in hazardous pressure system piping.

f. All piping welds shall be of the full penetration butt weld type unless specifically approved by Range Safety.

g. All piping and fitting butt welds used to fabricate hazardous pressure systems shall be 100 percent visually and radiographically inspected. Accept and reject criteria shall be in accordance with ANSI/ASME B31.3, Table 341.3.2A or Table K341.3.2A for pressure systems equal to or greater than 6000 psi.

3.11.2.4 Ground Support Pneumatic System Tubing

a. If welded, pneumatic distribution tubing should be annealed seamless, stainless steel Type 304/316 or 304L/316L. **NOTE:** Tubes may be joined by the use of precision 37^{o} flared ends and threaded fittings or by the use of special purpose butt welded studs containing a precision machined 37^{o} flare and threaded fittings.

b. 37^{o} flared end fittings shall be designed in accordance with precision type AN, MS or KSC-GP-425 Standards. The material should be type 316.

c. If used to join tubing, butt weld fittings shall be designed in accordance with KSC-GP-425 or equivalent. Material should be 304L or 316L.

d. All tubing and butt weld fitting welds shall be 100 percent radiographically inspected. The accept and reject criteria shall be in accordance with Table 1 of KSC-SPEC-Z-0016. **NOTE**: If this criteria cannot be met, the Range User shall submit alternate accept and reject criteria to Range Safety for review and approval.

e. Since flared tubing is not designed for service above 6000 psig, Range Safety approved super pressure tubing shall be used for service above 6000 psig.

f. The number of mechanical joints shall be minimized to reduce the probability of leakage.

g. Tube fittings with NPT connectors shall not be used in hazardous pressure systems.

3.11.2.5 Ground Support Pneumatic System Regulators

a. Regulators shall be selected so their working pressure falls within the center 50 percent of the total pressure range if it is susceptible to inaccuracies or creep at either end of the pressure range.

b. Manually operated regulators shall be selected so that overtorquing the regulator cannot damage soft seats to the extent that seat failure occurs.

c. Designs using uncontained seats are unacceptable.

d. Regulator functional failure shall not create a hazard to personnel.

e. Dome loaded pressure regulators shall withstand a differential pressure across the diaphragm and/or piston equal to the maximum rated inlet pressure without damage. A means of venting the dome loading circuit shall be provided.

f. For each stage of regulation, it is desirable that the ratio of upstream pressure to downstream pressure not exceed 5 for optimum control of pressure and flow and to minimize problems in sizing pressure relief devices.

g. Except for cylinder (K-bottle) regulators, pressure regulator bodies and other pressure containing parts should be constructed of 300 series stainless steel.

h. Pressure regulator actuators shall be capable of shutting off the fluid when the system is at the maximum possible flow and pressure.

i. The use of a sheathed flexible actuator such as push-pull wires and torque wires for regulator control is prohibited.

j. Remotely operated regulators shall be designed to be fail-safe if pneumatic or electric control power is lost.

k. All electrical control circuits for remotely actuated regulators shall be shielded or otherwise protected from hazardous stray energy.

l. A regulator shall not be used as a safety critical component or be required to function to prevent a failure that might injure personnel.

3.11.2.6 Ground Support Pneumatic System Valves

a. Valve actuators shall be operable under maximum design flow and pressure.

b. Remotely operated valves shall be designed to be fail-safe if pneumatic or electric control power is lost.

c. Balanced manual valves that use external balancing ports or vents open to the atmosphere shall not be used.

d. Valve bodies and other appropriate parts should be constructed of 300 series stainless steel.

e. Valve stem travel shall be limited by a positive stop at each extreme position.

f. The application or removal of force to the stem-positioning device shall not cause disassembly of the pressure containing structure of the valve.

g. Designs using uncontained seats are prohibited.

h. All electrical control circuits for remotely actuated valves shall be shielded or otherwise protected from hazardous stray energy.

i. Manually operated valves shall be designed so that overtorquing the valve stem cannot damage soft seats to the extent that seat failure occurs.

j. Inlet and outlet isolation valves shall be bidirectional valves capable of isolating the maximum allowable working pressure in both directions without seat failure.

k. Inlet and outlet isolation valves (shutoff valves) and appropriate intermediate vent valves shall be provided for shutdown and maintenance.

l. Local or remote stem-position indicators shall sense the position of the stem directly, not the position of the actuating device.

m. Valves used in flared tubing system applications shall be designed for panel or other rigid mounting.

n. Special care shall be taken in the design of oxygen systems to minimize the heating effect due to rapid increases in pressure.

o. Fast opening valves that can produce high velocity kinetic effects and rapid pressurization shall be avoided.

p. Valves that are not intended to be reversible shall be designed or marked so that they will not be connected in a reverse mode.

q. Systems shall have shutoff valves located as close to the supply vessel as practical and be readily accessible.

r. Check valves shall be provided where back flow of fluids would create a hazard.

s. The use of a sheathed flexible actuator such as push-pull wires and torque wires for valve control is prohibited.

t. All hazardous pressure system valves that shall remain in a CLOSED or OPEN position during sys-tem operation shall be protected against inadvertent actuation by mechanical stops or lock wires (access control may only be used if mechanical stops/lock wires are not feasible and Range safety concurs).

u. Remotely controlled valves shall provide for remote monitoring of OPEN and CLOSED positions.

3.11.2.7 Ground Support Pneumatic System Indicating Devices

a. A pressure indicating device shall be connected downstream of each pressure regulator on each storage system and on any section of the system where pressure can be trapped.

b. Remote readout pressure transducers are required when determined by Range Safety to monitor hazardous operations from a remote location.

c. All pressure gauges shall conform to the requirements of ANSI/ASME B40.1. *EXCEPTION: Pressure gauges that are part of a cylinder regulator assembly such as those used with cutting, welding, or other industrial equipment are exempt from these requirements as are gauges associated with pneumatic controllers, positioners, and other standard process control equipment*.

1. Gauges shall be selected so that the normal operating pressure falls between 25 percent and 75 percent of the scale range, except for gauges used in applications that require a wide range of operating pressure.

2. For applications requiring a wide range of operating pressure, the pressure gauges shall be selected so that the maximum pressure that can be applied shall not exceed 95 percent of the scale range of the gauge.

3. Pressure gauges shall be of one piece, solid front, metal case construction, using an optically clear shatterproof window made of high-impact, non-cracking plastic, heat-treated glass, or laminated glass.

4. All pressure gauges shall be equipped with a full diameter pressure release back that shall be sized for maximum flow without case rupture. **NOTE:** The use of blowout plugs is not recommended.

5. Gauges shall be securely attached to a panel or other rigid mounting.

d. All pressure gauge material that normally contacts the service fluid should be type 316 stainless steel. *EXCEPTION: Bourdon-tube bleed screws may be constructed of any 300 series stainless steel.*

e. If pressure gauge isolation valves are used, they shall be designed so that they can be lock wired in the OPEN position.

f. At a minimum, gauge installations shall be designed to have a 1-in. clearance in the back to allow unrestricted venting in the event the gauge vents.

g. Personnel and critical equipment shall be protected from potential venting hazards.

3.11.2.8 Ground Support Pneumatic System Flexible Hoses

a. Flexible hoses shall be used only when required for hookup of portable equipment or to provide for movement between interconnecting fluid lines when no other feasible means is available.

b. Flexible hoses shall consist of a flexible inner pressure carrier tube (compatible with the service fluid) constructed of elastomeric (typically polytetrafluoroethylene [PTFE]) or corrugated metal (typically 300 series stainless steel) material reinforced by one or more layers of 300 series stainless steel wire and/or fabric braid. **NOTE 1**: In applications where stringent permeability and leakage requirements apply, hoses with a metal inner pressure carrier tube should be used. **NOTE 2**: Where these hoses are used in a highly corrosive environment, consideration should be given to the use of Hastalloy C-22 in accordance with ASTM B575 for the inner pressure carrier tube and C-276 material for the reinforcing braid.

c. Hoses shall be provided with 300-series stainless steel end fittings of the coupling nut, 37^{o} flared type or with fittings to mate with the appropriately sized ANSI/ASME B16.5 flange or KC159 hub. **NOTE:** Other end fittings may be used for unique applications, subject to Range Safety approval.

d. Hoses over 2 ft long, pressurized to 150 psig or greater, shall meet the following restraint requirements:

1. The flex hose shall have safety chains or cables securely attached across each union or splice and at intervals not to exceed 6 ft.

2. Hose end restraints shall be securely attached to the structure in a manner that in no way interferes with the hose flexibility.

3. Restraint devices shall be capable of withstanding not less than 6 times the open line pressure force.

4. The design safety factor for restraint devices shall not be less than 3 on material yield strength.

5. Temporary flex hose installations may be weighted with 50-lb sand bags, lead ingots, or other suitable weights at intervals not to exceed 6 ft.

e. Flex hose installation shall be designed to avoid abrasive contact with adjacent structures or moving parts.

f. Flex hose assemblies shall not be installed in a manner that will place a mechanical load on the hose or hose fittings to an extent that will degrade hose strength or cause the hose fitting to loosen.

g. Flexible hose shall not be supported by rigid lines or components if excessive loads from flex hose motion can occur.

h. Flexible hose between two components may have excessive motion restrained where necessary, but shall never be rigidly supported by a tight rigid clamp around the flexible hose.

i. Flex hoses shall not be exposed to temperatures that exceed the rated temperature of the hose.

j. Flex hoses that are permitted to pass close to a heat source shall be protected with a fireproof boot or metal baffle.

k. Designs using convoluted, unlined bellows or flexible metal hoses shall be analyzed to verify premature failure caused by flow-induced vibration is precluded.

l. Acoustic coupling that can intensify the stresses caused by flow induced vibration shall be avoided by ensuring that normal fluid flow requirements do not exceed a velocity of Mach 0.2. **NOTE:** A guidance document for performing the flow-induced vibration analysis is MSFC 20MO2540.

m. The bend radius of flex hoses shall be designed to be no less than the safe minimum bend radius recommended in authoritative specifications for the particular hose and in no case less than 5 times the outside diameter of the hose.

n. A means of plugging or capping flex hoses shall be provided when the hose is not in use.

3.11.2.9 Ground Support Pneumatic System Pressure Relief Devices

3.11.2.9.1 Fixed Pressure Relief Devices.

a. All fixed pressure vessels shall be protected against overpressure by means of at least one conventional safety relief valve or pilot-operated pressure relief valve in accordance with ASME Code, Section VIII, Division 1, Paragraphs UG-125 through UG 136, or Division 2, Article R-1, as applicable.

b. A rupture disc may be installed between the pressure relief valve and the vessel provided that the limitations of ASME Code, Section VIII, Division 1, Paragraphs UG-127(a)(3)(b) and UG 127(a)(3)(c) or Division 2, Article R-1, Paragraphs AR-131.4 and AR-131.5 are met.

c. Particular care shall be taken to monitor and/or vent the space between the rupture disc and the relief valve as required.

d. All rupture discs installed in hazardous fluid systems shall be replaced every two years. **NOTE:** Providing a screen between the rupture disc and the valve to prevent rupture disc contamination of the relief valve should be considered.

e. Installation of the pressure relief devices shall be in accordance with ASME Code, Section VIII, Division 1, Paragraph UG-135 or Division 2, Article R-1.

f. The total relieving capacity of pressure relief devices shall be determined in accordance with ASME Code, Section VIII, Division 1, Paragraph UG-133 or Division 2, Paragraph AR150, as applicable. The required relieving capacity shall be provided by a single valve where possible.

g. Pressure relief devices shall be set to operate at a pressure not to exceed the MAWP of the vessel. [See ASME Code, Section VIII, Division 1, Paragraphs UG-134(A), UG-134(b), UG-134(c), and UG-134(d)(1)]

h. Negative pressure protection shall be provided for vessels not designed to withstand pressures below 1 atmosphere. **NOTE**: This protection can be accomplished by the use of check valves or negative pressure relief devices.

i. Pressure vessel relief devices shall be located so that other components cannot render them inoperative except as specified in ASME Code, Section VII, Division 1, Paragraphs UG-135(e)(1), UG-135(e)(2), and Appendix M, Paragraphs M-5 and M-6. **NOTE:** When a shutoff valve is allowed in accordance with the ASME Code, the valve type shall have provisions for being safety wired in the OPEN or CLOSED position.

j. The shutoff valve shall have permanent marking clearly identifying its position (OPEN or CLOSED).

3.11.2.9.2 Portable and Mobile Pressure Vessels.

a. DOT pressure vessels shall be protected against over pressure in accordance with 49 CFR.

b. DOT pressure vessels used and approved for use in a fixed ground based system shall be provided overpressure protection in accordance with the ASME Code.

3.11.2.9.3 Pressure Relief Devices for Systems and Subsystems.

a. A pressure relief valve shall be installed as close as is practical downstream of each pressure reducing device (regulator, orifice) or downstream of any source of pressure such as compressors, gas rechargers, and tube bank trailer whenever any portion of the downstream system cannot withstand the full upstream pressure. **NOTE:** The criteria for *withstand* is that the upstream pressure shall not exceed the MAWP of any pressure vessel or component downstream of the regulator or pressure source.

b. A pressure relief valve shall be installed downstream of the last GSE regulator prior to flight hardware interface.

c. A pressure relief valve shall be installed downstream of last GSE regulator prior to entering a container and/or black box purge system.

d. The relieving capacity of the relief valve shall be equal to or greater than the maximum flow capability of the upstream pressure reducing device or pressure source and shall prevent the pressure from rising more than 20 percent above the system MOP or that allowed by ANSI/ASME B31.3, whichever is less.

e. Pressure relief valves shall be set to operate at a pressure not to exceed 110 percent of the system MOP or that allowed by ANSI/ASME B31.3, whichever is less.

f. Pressure system relief devices shall have no intervening stop valves between piping being protected and the relief devices or between the relief device and the point of discharge except as allowed by ANSI/ASME B31.3, Paragraph 322.6.1. **NOTE:** When a shutoff valve is allowed in accordance with the ANSI or ASME Code, the valve shall have provisions for being safety wired in the OPEN or CLOSED position. The valve shall have permanent marking clearly identifying its position (OPEN or CLOSED).

3.11.2.9.4 Relief Device General Design Requirements.

a. The flow capacity for all relief devices shall be certified in accordance with ASME Code, Section VIII, Division 1, Paragraph UG-127, UG-129, UG 131, and UG 132, as applicable.

b. The body and other pressure containing parts for pressure relief devices should be 300-series stainless steel. *EXCEPTION: DOT cylinders or trailer relief devices may contain parts of brass or bronze.*

c. The relief valve outlet piping shall be sized in accordance with ASME VIII, Division 1, UG-135(g).

d. The static back pressure developed at the discharge flange of the relief valve shall be held to within 10 percent of the set pressure of the relief valve.

e. All relief valves and piping shall be structurally restrained to eliminate any thrust effects from transferring moment forces to the vessel nozzles or lines.

f. The effects of the discharge from relief devices shall be assessed and analyzed to ensure that operation of the device will not be hazardous to personnel or equipment. Items to be analyzed are thrust loads, noise, impingement of high velocity gas or entrained particles, toxicity, oxygen enrichment, flammability, and oxygen deprivation.

g. All pressure relief devices shall be vented separately unless the following can be positively demonstrated:

1. The creation of a hazardous mixture of gases in the vent system and the migration of hazardous gases into an unplanned environment is impossible.

2. The capacity of the vent system is adequate to prevent a pressure rise more than 20 percent above MOP or exceed 10 percent of the set pressure of the valve in accordance with ASME Section VIII, Division 1, Appendix M, Paragraph M-8. **NOTE:** The analysis shall assume that all relief valves connected to the vent system are open and flowing full capacity.

3.11.2.10 Ground Support Pneumatic System Vents

a. Pressure systems shall be designed so that pressure cannot be trapped in any part of the system without vent capability. *EXCEPTION: Loosening of fittings to vent trapped pressure is allowed when the fluid under pressure is nonhazardous and only for the purpose of calibrating or replacing pressure gauges or transducers that are provided with an upstream isolation valve where the total trapped volume does not exceed 1 and 1/2 cubic in.*

b. Vent system outlets shall be in a location normally inaccessible to personnel and shall be conspicuously identified.

c. Vent outlets shall be protected against rain intrusion and entry of birds, insects, and animals.

d. Oxidizer and fuel vent outlets to the atmosphere shall be separated sufficiently to prevent mixing of vented fluids.

e. All vent outlets shall be designed to preclude accumulation of vented fluid in dangerous concentrations in areas frequented by unprotected personnel or motor vehicles.

f. Vent line supports shall be designed to withstand reaction loads due to the actuation of safety relief devices in accordance with ANSI/ASME B31.3, Paragraph 322.6.2.

g. Each line venting into a multiple use vent system shall be protected against back pressurization by a check valve if the upstream system cannot withstand the back pressure or where contamination of the upstream system cannot be tolerated.

3.11.2.11 Test Requirements for Ground Support Pneumatic Systems Prior to Assembly

a. All permanently installed pressure vessels except DOT vessels shall be hydrostatically tested in accordance with ASME Code, Section VIII, Division 1, Paragraph UG-99, UG-100 or Division 2, Article T-3 or T-4, as applicable.

b. Pressure vessels designed to meet DOT specifications shall undergo qualification and proof testing in accordance with DOT requirements.

c. All other fluid system components such as piping, tubing, flex hoses, valves, filters, fittings, and pressure regulators (not including pressure gauges, transducers, or rupture discs) shall be hydrostatically tested to a minimum of 1.5 times the component MAWP for a minimum of 5 min.

d. Hydrostatic or pneumatic testing shall demonstrate that there is no distortion, damage, or leakage of components at the appropriate test level pressure.

e. Both the inlet and discharge sides of a relief valve shall be hydrostatically tested. When the discharge side has a lower pressure rating than the inlet side, they are to be hydrostatically tested independently.

f. The following inspections shall be performed after hydrostatic testing:

1. Mechanical components such as valves, regulators, piping, and fitting shall be inspected for distortion or other evidence of physical damage. Damaged components shall be rejected.

2. After completion of the hydrostatic tests, a function and leak test shall be performed at the MAWP of the component.

g. Pressure relief valves shall be tested for proper setting prior to installation and periodically thereafter.

h. Pressure gauges and transducers shall be hydrostatically tested to a minimum of 1.5 times the system MOP.

i. Pressure gauges and transducers shall be calibrated prior to installation and periodically thereafter.

j. Pneumatic testing to a test pressure of 1.25 times MAWP in lieu of hydrostatic testing is permissible if hydrostatic testing is impractical, impossible, or will jeopardize the integrity of the component or system. **NOTE**: Prior approval for pneumatic proof testing at the Ranges shall be obtained from Range Safety.

k. Components may be initially hydrostatically tested to 1.5 times the system MOP after installation in a system. **NOTE:** This approach should be avoided if possible and shall be approved by Range Safety.

3.11.2.12 Test Requirements for Ground Support Pneumatic Systems After Assembly

3.11.2.12.1 Hydrostatic Tests. All newly assembled pressure systems shall be hydrostatically tested to 1.5 times MOP prior to use. **NOTE**: Where this is not possible, Range Safety will determine the adequacy of component testing and alternate means of testing the assembled system.

3.11.2.12.2 Leak Tests.

a. All newly assembled pressure systems, except systems designed, fabricated, inspected, and tested in accordance with DOT requirements, shall be leak tested at the system MOP prior to first use at the Ranges.

b. This test shall be conducted at the Ranges unless prior approval from Range Safety has been obtained.

c. Minimum test requirements are as follows:

1. The gas used during the leak test shall be the same as the system fluid media except those used for hazardous gas systems. A system compatible non-hazardous gas may be used that has a density as near as possible to the system fluid (for example, helium should be used to leak test a gaseous hydrogen system).

2. At a minimum, all items such as mechanical connections, gasketed joints, seals, valve bonnets, and weld seams shall be visually bubble tight for a minimum of 1 min when leak tested with MIL-L-25567 Type 1 or equivalent leak test solution.

3. Alternate methods of leak testing such as the use of portable mass spectrometers may be approved on a case-by-case basis.

4. Non-hazardous liquid systems may be leak tested using the normal system service.

3.11.2.12.3 System Validation and Functional Tests.

a. All newly assembled pressure systems shall have a system validation test and a functional test of each component at system MOP prior to first operational use at the Ranges.

b. These tests shall be conducted at the Ranges unless prior approval from Range Safety has been obtained.

c. Minimum test requirements are as follows:

1. Tests shall demonstrate the functional capability of all components such as valves, regulators, orifices, and gauges.

2. All operational sequences for the system shall be executed.

3. All shutoff and block valves shall be leak checked downstream to verify their shutoff capability in the CLOSED position.

3.11.2.12.4 Bonding and Grounding Tests. All newly assembled pressure systems that contain flammable/combustible fluids shall be tested to verify that the requirements of the **Ground Support Pressure Systems Bonding and Grounding** section of this Chapter have been met.

3.11.2.13 Periodic Test Requirements for Ground Support Pneumatic Pressure System Components

a. Flex hoses shall be hydrostatically proof tested to 1.5 times their MAWP once a year. *EXCEPTION: This requirement does not apply to flex hoses that are permanently installed, located, and operated in an environment that does not exceed the rated temperature, pressure, and shelf life of the hose.*

b. At least annually, all permanently installed flex hoses shall be visually inspected over their entire length for damaged fittings, broken braid, kinks, flattened areas, or other evidence of degradation.

c. Pressure gauges and transducers shall be calibrated once a year.

d. Pressure relief valves shall be tested for proper setting and operation once a year.

e. All newly assembled pressure systems that contain flammable or combustible fluids shall be tested to verify that the bonding and grounding requirements of the **Ground Support Pressure System Bonding and Grounding** section of this Chapter have been met.

3.11.2.14 Testing Modified and Repaired Ground Support Pneumatic Systems

a. Any pressure system or system component including fittings or welds that has been repaired, modified, or possibly damaged, subsequent to having been hydrostatically tested, shall be retested hydrostatically to 1.5 time MAWP prior to reuse. **NOTE:** Replacement of gaskets, seals, and valve seats that do not affect the structural integrity does not require a retest.

b. After hydrostatic testing, modified or repaired pneumatic systems shall be leak tested at the system MOP prior to placing them back in service. **NOTE:** This test shall be conducted at the Ranges unless prior approval has been obtained from Range Safety.

c. After hydrostatic testing, modified or repaired pneumatic systems shall be functionally tested at the system MOP prior to reuse.

d. All pneumatic system mechanical joints affected in the disconnection, connection, or replacement of components shall be leak tested at the system MOP before being placed back in service.

3.11.3 Ground Support Hydraulic Systems

3.11.3.1 Ground Support Hydraulic System General Design Requirements

a. Where necessary, hydraulic system “low-points” shall be fitted with a drain fitting (bleed ports) to allow draining of condensates or residue. **NOTE:** Entrapped air, moisture, and cleaning solvents are examples of foreign substances that may be hazardous to the system, component, or control equipment.

b. Bleed ports should be located so that they can be operated with minimal removal of other components and permit the attachment of a hose to direct the bleed off material into a container, away from the positions of the operators.

c. Test points shall be provided on hydraulic systems so that disassembly for test is not required.

d. Test points shall be easily accessible for attachment of ground test equipment.

e. For all power-generating components, pump pulsations shall be controlled to a level that does not adversely affect system tubing, components, and support installation.

f. When two or more hydraulic actuators are mechanically tied together, only one lock valve shall be used to hydraulically lock all the actuators.

g. The ambient operating temperature for hydraulic systems shall not exceed 275°F for systems using petroleum based fluids.

h. Fluids for systems operating at temperatures higher than 275°F shall be fire resistant or fireproof for the intended service.

i. Where system leakage can expose hydraulic fluid to potential ignition sources, fire resistant or flameproof hydraulic fluid shall be used.

j. All hydraulic piping installations shall be designed, installed, and tested in accordance with ANSI/ASME B31.3.

3.11.3.2 Ground Support Hydraulic System Accumulators and Reservoirs

a. Accumulators and reservoirs that are pressurized with gas to pressures greater than 250 psig shall be designed, constructed, tested, certified, and code stamped in accordance with ASME Code, Section VIII, Division 1 or Division 2.

b. Hydraulic system reservoirs shall be provided with a fluid level indicator. **NOTE:** If a sight glass is used for a liquid level indicator, it shall be properly protected from physical damage.

c. Only inert gases shall be used in pressurization accumulators in systems operating at pressures in excess of 200 psi or temperatures over 160°F unless adequate fire and explosion resistance is demonstrated.

d. For a gas pressurized reservoir, the gas pressure shall be controlled by an externally non-adjustable pressure regulating device to control the gas pressure in the reservoir.

e. Hydraulic systems having reservoir filling caps shall include design provisions that will automatically vent the reservoir opening.

3.11.3.3 Ground Support Hydraulic System Pumps

a. The *Standards of the Hydraulic Institute* should be used as a guide in selecting a safe pump.

b. Gear pumps shall not be used for high pressure applications.

c. The inlet pressure of hydraulic pumps should be controlled to prevent cavitation effects in the pump passage or outlets.

d. Hydraulic pumps required to provide emergency power shall not be used for any other function.

e. Hydraulic pressure systems shall have regulators with a pressure relieving or self-bleeding feature.

3.11.3.4 Ground Support Hydraulic System Pressure Gauges

a. Pressure snubbers shall be used with all hydraulic pressure transmitters, hydraulic pressure switches, and hydraulic pressure gauges. *EXCEPTION: Pneumatic pressure gauges are excluded from this requirement.*

b. A gauge indicating accumulator gas pressure shall never be used to indicate equivalent hydraulic pressure.

3.11.3.5 Ground Support Hydraulic System Pressure Relief Devices

a. A pressure relief valve shall be installed as close as is practical downstream of each pressure reducing device (regulator or orifice) or downstream of any source of pressure (pump, reservoir, or accumulator) whenever any portion of the downstream system cannot withstand the full upstream pressure. **NOTE:** The criteria for *withstand* is that the upstream pressure shall not exceed the MAWP of any component downstream of the regulator or pressure source.

b. A pressure relief valve shall be installed downstream of the last GSE regulator prior to flight hardware interface.

c. The relieving capacity of the relief devices shall be equal to or greater than the maximum flow capacity of the upstream pressure source and shall prevent the pressure from rising more than 20 percent of MOP or that allowed by ANSI/ASME 31.3, Paragraphs 301.2.2 and 322.6.3, whichever is less.

d. Pressure relief valves shall be set to operate at a pressure not to exceed 110 percent of the system MOP or that allowed by ANSI/ASME, whichever is less.

e. The effects of discharge from relief devices shall be assessed and analyzed to ensure that operation of the device will not be hazardous to personnel or equipment. **NOTE:** Items to be analyzed are thrust loads, toxicity, combustibility, and flammability.

f. Pressure system relief devices shall have no intervening stop valves between piping being protected and the relief devices or between the relief device and the point of discharge, except as allowed per ANSI/ASME B31.1, Paragraph 322.6.1.

g. When a shutoff valve is allowed in accordance with the ASME Code, the valve type shall have provisions for being safety wired in the OPEN or CLOSED position.

h. The shutoff valve shall have permanent marking clearly identifying it position (OPEN or CLOSED).

i. Thermal expansion relief valves shall be installed as necessary to prevent system damage from thermal expansion of hydraulic fluid.

j. The thermal relief valve setting shall not exceed either the system test pressure or 120 percent of the system MOP.

3.11.3.6 Test Requirements for Ground Support Hydraulic System Components Prior to Assembly

a. All accumulators and reservoirs that are pressurized with gas to pressures greater than 250 psig shall be hydrostatically tested in accordance with ASME Code, Section VIII, Division 1, Paragraph UG-99, UG-100 or Division 2, Article T-3 or T-4, as applicable.

b. All other hydraulic system components (not including pumps, pressure gauges and transducers, and rupture disks) shall be hydrostatically tested to 1.5 times the component MAWP for a minimum of 5 min. **NOTE:** Testing shall demonstrate that the components will sustain test pressure levels without distortion, damage, or leakage.

c. Both the inlet and outlet sides of a relief valve shall be hydrostatically tested. When the discharge side has a lower pressure rating than the inlet side, they are to be hydrostatically tested independently.

d. The following inspections shall be performed after hydrostatic testing:

1. Mechanical components such as valves, filters, piping, fittings, and regulators shall be inspected for distortion or other evidence of physical damage. Damaged components shall be rejected.

2. After completion of hydrostatic tests, functional and leak tests shall be performed at the component MAWP.

e. Pressure gauges and transducers shall be calibrated prior to installation and periodically thereafter.

f. Pressure relief valves shall be tested for proper setting prior to installation and periodically thereafter.

g. Components may be initially hydrostatically tested to 1.5 times the system MOP after installation in a system. **NOTE:** This approach should be avoided, if possible. Range Safety approval is required to use this approach.

3.11.3.7 Test Requirements for Ground Support Hydraulic Systems After Assembly

3.11.3.7.1 Hydrostatic Testing. All newly assembled hydraulic pressure systems shall be hydrostatically tested to 1.5 times MOP prior to use. **NOTE:** Where this is not possible, Range Safety will determine the adequacy of component testing and an alternate means of testing the assembled system.

3.11.3.7.2 Leak Tests.

a. All newly assembled hydraulic systems shall be leak tested at the system MOP prior to first use at the Ranges.

b. This test shall be conducted at the Ranges unless prior approval from Range Safety has been obtained.

c. Minimum test requirements are as follows:

1. The fluid used during the leak test shall be the same as the system fluid media.

2. Mechanical connections, joints with gaskets, seals, valve bonnets, and other components shall be inspected for leaks while monitoring for any pressure decay.

3.11.3.7.3 System Validation and Functional Tests.

a. All newly assembled hydraulic pressure systems shall have a system validation test and a functional test of each component at system MOP prior to first use at the Ranges.

b. These tests shall be conducted at the Ranges unless prior approval from Range Safety has been obtained.

c. Minimum test requirements are as follows:

1. Tests shall demonstrate the functional capability of all components such as valves, pumps, orifices, and gauges.

2. All operational sequences for the system shall be executed.

3. All shutoff and block valves shall be leak checked downstream to verify their shutoff capability in the CLOSED position.

3.11.3.8 Periodic Test Requirements for Ground Support Hydraulic System Components

a. Flex hoses shall be hydrostatically tested to 1.5 times their MAWP once a year. *EXCEPTION: This requirement does not apply to flex hoses that are permanently installed, located, and operated in an environment that does not exceed the rated temperature, pressure and shelf life of the hose.*

b. All permanently installed flex hoses shall be visually inspected over their entire length at least annually for damaged fittings, broken braid, kinks, flattened areas, or other evidence of degradation.

c. Pressure gauges and transducers shall be calibrated once a year.

d. Pressure relief valves shall be tested for proper setting and operation once a year.

3.11.3.9 Testing Modified and Repaired Ground Support Hydraulic Systems

a. Any hydraulic system or system component, including fittings or welds, that has been repaired, modified, or possibly damaged, subsequent to having been hydrostatically tested, shall be retested hydrostatically prior to reuse. **NOTE:** Replacement of gaskets, seals, and valve seats that do not affect the valve structural integrity does not require a retest.

b. After hydrostatic testing, modified or repaired hydraulic systems shall be leak tested at the system MOP before being placed back in service. **NOTE:** This test shall be conducted at the Ranges unless prior approval from Range Safety has been obtained.

c. After hydrostatic testing, modified or repaired hydraulic systems shall be functionally tested at the system MOP prior to being placed back in service.

d. All hydraulic system mechanical joints affected in the disconnection, connection, or replacement of components shall be leak tested at the system MOP.

3.11.4 Ground Support Hypergolic Propellant Systems

This section contains minimum design requirements for all fixed, mobile, or portable equipment used to handle hypergolic propellants (Nitrogen Tetroxide [N_2O_4], Hydrazine [N_2H_4,] Unsymmetrical Dimethyl Hydrazine [UDMH], Aerozine 50 [A-50], Mono Methyl Hydrazine [MMH]).

3.11.4.1 Ground Support Hypergolic Propellant System General Design Requirements

a. GSE used to handle hypergolic propellant systems shall be designed to ensure that all incompatible fuels and oxidizers are separated so that operations during the prelaunch phase cannot cause inadvertent mixing of the propellants.

b. Propellant systems shall have low point drain capability.

c. Low point drains shall be accessible and located in the system to provide the capability of removing propellant from the tanks, piping, lines, and components.

d. Pumps used in hypergolic propellant systems shall be of the centrifugal type and specifically designed for pumping hypergolic propellants.

e. Bi-propellant propellant systems shall have the capability of loading fuel and oxidizer systems one at a time.

f. Systems shall be designed so that the system being loaded (flight propulsion systems or ground propellant tanks) and the propellant loading system can be commonly grounded and bonded during propellant transfer operations. **NOTE:** Loading systems include portable vessels and units.

g. For failure modes that could result in a time-critical emergency, provision shall be made for automatic switching to a safe mode of operation. **NOTE**: Caution and warning signals shall be provided for these time-critical functions.

h. Pneumatic systems servicing fixed, portable, and mobile hypergolic propellant systems shall comply with the **Ground Support Pneumatic Systems** section of this Chapter.

i. Components used in any fuel or oxidizer system shall not be interchanged after exposure to the respective media.

j. Lubricants for hypergolic systems shall be approved compatible lubricants only. **NOTE**: See KSC-SPEC-Z-0006 for guidance.

3.11.4.2 Mobile and Portable Ground Support Hypergolic Propellant Systems

a. Mobile equipment for public and Range highway use shall be designed to meet the requirements in 49 CFR, Subpart 6, Parts 100 through 199. **NOTE:** A copy of any DOT approved exemptions shall be provided to Range Safety.

b. Portable equipment used for storage or transportation of hypergol propellants or hypergol waste shall be designed to meet applicable requirements for packaging set by the DOT in 49 CFR. **NOTE:** Consideration in the design shall be given to the limitations imposed on individuals dressed in SCAPE.

3.11.4.3 Ground Support Pneumatic and Hypergolic Propellant Systems Interface

The minimum design requirements for controlling the migration of liquid or gas hypergolic propellant into an associated pneumatic system are as follows:

a. Each pneumatic branch line that interfaces with a hypergolic propellant system shall have a hand-operated shutoff valve upstream of a regulator and a spring-loaded, poppet-type check valve to permit positive shutoff of the pneumatic supply and prevent back flow through the branch.

b. Each pneumatic branch supply shall interface with only one type of hypergolic propellant (fuel or oxidizer).

c. A sampling port shall be provided upstream and downstream of each regulator referred to in the *a* above to permit periodic sampling and analysis of the pneumatic medium for hypergol contamination.

d. A single pressure gauge shall be provided at some point downstream either in the pneumatic system or the hypergol system of each check valve referred to in paragraph *a* above to indicate the pressure in the hypergolic propellant system.

e. Gage calibration ports shall be designed to limit potential impingement of contaminated gas on personnel.

f. Downstream of the pneumatic pressure regulator, including the regulator seat, the pneumatic system shall be constructed of materials that are compatible with all of the hypergolic propellants serviced by the pneumatic supply.

g. Downstream of the pneumatic pressure regulator, the pneumatic system shall be identified and marked as a hypergolic system.

3.11.4.4 Ground Support Fixed and Mobile Hypergolic Propellant Storage Vessels

a. All permanently installed pressure vessels shall be designed, constructed, tested, certified, registered, and code stamped in compliance with the ASME Boiler and Pressure Vessel Code, Section VIII, Pressure Vessels (Unfired), Division 1 or Division 2, Lethal Service.

b. All ASME code stamped vessels shall be registered with the National Board of Boiler and Pressure Vessel Inspectors.

c. The following additional design, fabrication, and inspection requirements shall be met:

1. Pressure vessels shall be designed with an opening for inspection purposes.

2. Pressure retaining welds including all shell, head nozzle and nozzle to head and shell welds shall be inspected using volumetric NDE techniques.

3. At a minimum, all attachment welds such as supports, lugs, pads, and name plates shall be inspected using surface NDE techniques.

4. Welded attachments such as stiffening rings or supports shall be continuously welded.

5. Welded and bolted attachments to the pressure vessel such as piping, supports, ladders, and platforms shall be minimized.

6. External and internal surfaces of vessels shall be free of crevices and other areas that can trap moisture or contaminants.

7. All attachments shall be positioned in such a manner that no attachment weld will overlap any category A or B weld as defined by ASME Code, Section VIII, Division 1 or Division 2.

8. All fixed pressure vessels exposed to the atmosphere and winds shall be designed with a minimum 2 psig external pressure load.

9. Pressure vessel material shall be stainless steel, type 304L, unless otherwise approved. **NOTE:** The use of high carbon content stainless steel such as type 304 is subject to chromium carbide precipitation during welding and bending activities.

10. A 1/16-in. additional thickness shall be added to the design wall thickness above the minimum required for pressure, liquid head, and other load conditions.

11. All pressure vessels shall be designed to allow for a minimum 10 percent ullage space at full load conditions.

12. Pressure vessel saddle support shall be designed in accordance with ASME Boiler and Pressure Vessel Code, Appendix G sanctioned guidelines, such as those developed by L.P. Zick, or a detailed (finite element) analysis shall be performed.

13. Consideration shall be given to anchor bolt design capability for hold down in the event of a deluge water filled bay (buoyant force of vessel), if applicable.

14. One of the two supports of a fixed vessel shall be capable of providing for expansion and contraction of the vessel.

15. A suitable anti-friction solid material shall be placed between sliding surfaces.

16. Slots shall be provided for bolts to account for expansion.

17. All fixed hypergolic fuel vessels shall be designed with a minimum value of 75 psig MAWP.

18. All fixed hypergolic oxidizer vessels shall be designed with a minimum value of 100 psig MAWP.

19. Liquid sensors, suitable for indicating the presence or absence of liquid, shall be provided.

(a) Metals that could come in contact with the service medium shall be type 304 or 316 stainless steel.

(b) Liquid level indicators that contain welded portions (typically magnetic float type) shall be constructed from type 304L or 316L stainless steel.

(c) The use of glass faced or radiation source emitting liquid level indicators is prohibited. Other prohibited types include capacitance, conductive, and pressure/density types due to historical operational failures and continuous maintenance problems.

(d) Sight glasses used for liquid level indicators shall be protected from physical damage.

20. Waste tank design and operating criteria shall be determined by the type (hazardous or nonhazardous) to be maintained in the specified tank.

(a) All underground hazardous waste tanks and ancillary piping shall comply with the requirements in 40 CFR 264.193 and 40 CFR, Part 280.

(b) Waste tanks may be located above ground or underground.

(c) All underground waste tanks and ancillary piping shall have secondary containment systems with leak detection capability.

21. Portable and/or mobile pressure vessels used for the transportation of hazardous materials shall be designed, fabricated, inspected, and tested in accordance with 49 CFR.

3.11.4.5 Ground Support Hypergolic Propellant System Piping

3.11.4.5.1 Piping Design and Material.

a. All hypergol piping design shall be in accordance with ANSI/ASME B31.3, Category M.

b. Pipe shall conform to ANSI/ASME B36.19.

c. The pipe material shall comply with ASTM A312, type 304L or 316L.

d. Only seamless, cold-drawn pipes shall be used for hypergol services.

e. NPT connectors shall not be used.

3.11.4.5.2 Pipe Fittings.

a. Pipe fittings shall be full penetration butt weld only and shall conform to ANSI B16.9.

b. Fittings shall be type 304L or 316L material conforming to ASTM A403.

c. Welded fittings such as tees, elbows, reducers, crosses, lap joint, and stub ends shall be seamless (WP-S) or welded and X-rayed (WP-WX) type.

d. Socket weld and pipe thread fittings are not permitted.

3.11.4.5.3 Flanges and Flange Connections.

a. Flanged connections shall use weld neck or lap joint flanges only.

b. Pipe flanges shall conform to ANSI B16.5 and be constructed of forged type 304L or 316L material in accordance with ASTM A182.

c. All flanges shall be raised face and shall be concentric serrated per MSS-SP-6.

d. Flange gaskets shall conform to ANSI B16.21 and shall be installed between flanges at all flanged connections.

e. Flange gasket material shall be shown to be compatible with the hypergol.

f. Flange bolting and studs shall conform to ANSI/ASME B18.2.1 recommended dimensions and shall use ANSI/ASME B1.1 coarse threads.

g. Bolt materials shall be in accordance with ASTM A193 (type 304 stainless steel) or ASTM A320 (type 316 stainless steel).

h. Nuts for flange bolting and studs shall conform to ASME B18.2.2 heavy hex type per ASTM A194 (type 304 stainless steel) or ASTM A194 (type 316 stainless steel) and shall use ANSI/ASME B1.1 coarse threads.

i. Type 304 or 316 stainless steel washers shall be used at both ends of each flange bolt or stud.

3.11.4.5.4 Piping and Fitting Weld Inspection.

a. All piping and fitting welds shall be 100 percent radiographically inspected.

b. The accept and reject criteria shall be in accordance with Table 341.3.2A of ANSI/ASME B31.3.

3.11.4.6 Ground Support Hypergolic Propellant System Tubing

a. Tubing shall be seamless, type 304 or type 316 stainless steel per ASTM A269 or KSC-SPEC-Z-0007.

b. Tubing used with AN or MS fittings shall be flared per MS33584, and tubing used with KSC-GP-425 fittings shall be flared per KSC-GP-425.

c. Mechanical connections in tubing shall use type 316 stainless steel precision-type 37☜ threaded fittings per AN, MS, or KSC-GP-425 standards. All seals for tube fittings shall be teflon. Crush washers are prohibited.

d. Fabrication and installation of tubing using KSC-P-425 fittings shall be in accordance with KSC-SPEC-Z-0008.

e. The number of mechanical joints in tubing systems shall be kept to a minimum.

f. All tubing welds shall be 100 percent radiographically inspected. The accept and reject criteria shall be in accordance with Table I of KSC-SPEC-Z-0016. **NOTE:** If this criteria cannot be met, the Range User shall submit alternate accept and reject criteria to Range Safety for review and approval.

g. NPT connectors shall not be used.

3.11.4.7 Ground Support Hypergolic Propellant System Valves

a. Metal-to-metal seats for shutoff valves in hypergolic service are not permitted without Range Safety approval.

b. Remote operated flow control valves shall be operated pneumatically, electrically, or hydraulically and shall be capable of fail-safe operation to either the OPEN or CLOSED position. **NOTE:** Determination of fail-safe mode (the OPEN or CLOSED position) shall depend on the system characteristics and shall be approved by Range Safety.

c. Check valves shall be the spring-loaded type with soft seats.

d. Electrically operated (solenoid) valves may be used, although pneumatically operated valves are preferred. Both primary and secondary valve seals shall be compatible with the service fluid.

e. Metal valve parts in contact with the working fluid shall be type 304, 304L, 316, or 316L stainless steel.

f. Manual and remote controlled valve actuators shall be capable of completely opening or closing shutoff valves under the maximum possible pressure and flow conditions in the system.

g. Valve stem travel shall be limited by a positive stop at each extreme position.

h. The application or removal of force to a valve stem positioning device shall not cause disassembly of the pressure containing structure of the valve.

i. Valves with uncontained seats are prohibited.

j. All electrical control circuits for remotely actuated valves shall be shielded or otherwise protected from hazardous stray energy.

k. Manually operated valves shall be designed so that overtorquing the valve stem cannot damage soft seats to the extent that seat leakage occurs.

l. Isolation valves shall be bi-directional and capable of isolating MAWP in both directions without seat failure.

m. Inlet and outlet isolation valves and appropriate intermediate vent valves shall be provided for shutdown and maintenance.

n. Local or remote stem position indicators shall sense the position of the stem directly, not the position of the actuating device.

o. Valves used in flared tubing system applications shall be designed for panel or other rigid mounting.

p. Valves that are not intended to be reversible shall be designed or marked so that they will not be connected in a reverse mode.

q. Systems shall have shutoff valves located as close to the supply vessel as practical and be readily accessible.

r. Check valves shall be provided where back flow of fluids would create a hazard.

s. The use of sheathed flexible actuators such as push pull wires and torque wires for valve control is prohibited.

t. Valve connectors and connections shall be designed, selected, or located (or as a last resort marked) so that they are unlikely to be inadvertently connected to an incompatible system.

u. All hazardous pressure system valves that shall remain in a CLOSED or OPEN position during system operation shall be protected against inadvertent actuation by mechanical stops, lock wires, or access control.

v. Remotely controlled valves shall provide for remote monitoring of OPEN and CLOSED positions.

3.11.4.8 Ground Support Hypergolic Propellant System Indicating Devices

a. A pressure indicating device such as a pressure gauge, pressure switch, or pressure transducer shall be connected downstream of each pressure regulator, on each storage system, and on any section of the system where pressure can be trapped.

b. As determined by Range Safety, remote readout pressure transducers are required when it is necessary to monitor hazardous operations from a remote location.

c. Pressure gauges shall conform to the ANSI/-ASME B40.1. except as specified below:

1. Gauges shall be selected so that the normal operating pressure falls between 25 percent and 75 percent of the scale range, except for gauges used in applications that require a very wide range of operating pressure. For these applications, the pressure gauges shall be selected so that the maximum pressure that can be applied shall not exceed 95 percent of the scale range of the gauge.

2. Pressure gauges shall be of one-piece, solid-front, metal case construction, with an optically clear shatterproof window of high-impact, non-cracking plastic, heat-treated glass, or laminated glass.

3. All pressure gauges shall be equipped with a full diameter pressure release back capable of being sized for maximum flow without case rupture. The use of blowout plugs is not recommended.

4. Gauges shall be securely attached to a panel or other rigid mounting.

5. All pressure gauges should be provided with a bourdon tube tip bleeder or equivalent device to facilitate cleaning.

d. All pressure gauge material normally in contact with hypergolic fluid shall be type 316 stainless steel except that the bourdon-tube bleed screw may be made from any of the 300 series stainless steels.

e. Each pressure indicating device shall be provided with an isolation valve and a test connection (test port) between the isolation valve and the pressure indicating device.

f. Trapped volume between the isolation valve and the pressure indicating device shall not exceed 1.5 cubic in.

g. Pressure gauge isolation valves shall be designed so that they can be lock wired in the OPEN position.

h. Gauge installations shall be designed to have a minimum 1-in. clearance in the back to provide unrestricted venting in the event the gauge vents.

i. Personnel and critical equipment shall be protected from potential venting hazards.

3.11.4.9 Ground Support Hypergolic Propellant System Flexible Hoses

a. Flexible hoses shall be used only when required for hookup of portable and mobile equipment or to provide for movement between interconnecting fluid lines when no other feasible means are available.

b. Hoses shall consist of a seamless polytetrafluoroethylene (PTFE) or compounded PTFE inner tube reinforced with a 300-series stainless steel wire construction of braid or spiral wrap, or a combination thereof, or shall consist of a flexible 300-series stainless steel pressure carrier reinforced with 300-series stainless steel braid.

c. Hoses shall be provided with 300-series stainless steel end fittings of the coupling nut, 37☜ flared type, or with the appropriate ANSI/ASME B16.4 raised-face pipe flange with concentric serrations per MSS-SP-6. **NOTE**: Other end fittings may be used for unique applications, subject to Range Safety approval.

d. Flex hose installation shall be designed to avoid abrasive contact with adjacent structures or moving parts.

e. Flex hose assemblies shall not be installed in a manner that will place a mechanical load on the hose or hose fittings to an extent that will degrade hose strength or cause the hose fitting to loosen.

f. Flexible hose shall not be supported by rigid lines or components if excessive loads from flex hose motion can occur.

g. Flexible hose between two components may have excessive motion restrained where necessary, but shall never be rigidly supported by a tight rigid clamp around the flexible hose.

h. The bend radius of flex hoses shall be designed to be no less than the safe minimum bend radius recommended in authoritative specifications for the particular hose and in no case less than 5 times the outside diameter of the hose.

i. A means of plugging or capping flex hoses shall be provided when they are not in use.

j. All flexible hoses that are not lined shall be subjected to a flow-induced vibration analysis. **NOTE**: A guidance document for performing this analysis is MSFC 20MO2540.

3.11.4.10 Ground Support Hypergolic Propellant System Pressure Relief Devices

a. All fixed hypergolic pressure vessels shall be protected from overpressure by means of at least one spring-loaded type relief valve. **NOTE:** Required relieving capacity should be provided by means of a single relief valve, if possible. Rupture disks alone shall not be used to protect against overpressure.

1. A rupture disc may be installed upstream or downstream of a hypergol vessel relief valve, provided the limitations of ASME Code, Section VIII, Division 1, Paragraphs UG-127(a)(3)(b) and UG-127(a)(3)(c), or Division 2, Article R-1, Paragraphs AR-131.4 and AR-131.5 are met.

2. The space between a rupture disc and a relief valve shall be designed to allow annual testing for leakage and/or contamination.

3. All rupture discs shall be replaced every two years or sooner based on manufacturer recommendations. **NOTE:** Providing a screen between the rupture disc and the valve to prevent rupture disc contamination of the relief valve should be considered.

4. Installation of relief valves shall be in accordance with ASME Code, Section VIII, Division 1, Paragraph UG-135 or Division 2, Article R-1.

5. The required total relieving capacity required shall be determined in accordance with ASME Code, Section VIII, Division 1, Paragraph UG-133 or Division 2, Paragraph AR-150, as applicable.

6. Relieving capacity required due to possible exposure of hypergol vessels to fire conditions shall be incorporated in accordance with the ASME Code, Section VIII, Division 1, Appendix M, Paragraph M-14, and applicable references therein. **NOTE:** Reductions in required relieving capacity due to lowering of heat input because of water deluge systems should be considered in the design. Refer to NFPA codes for Compressed Gas Association (CGA) correlation to reduced heat input factors.

7. Pressure relief devices shall be set to operate at a pressure not to exceed the MAWP of the vessel. See ASME Code, Section VIII, Division 1, Paragraphs UG-134(a), UG-134(b), UG-134(c), and UG-134(d)(1).

8. Negative pressure protection shall be provided for vessels not designed to withstand pressures below 1 atmosphere. **NOTE**: This protection can be accomplished by the use of check valves or negative pressure relief devices.

b. DOT pressure vessels shall be protected against overpressure in accordance with 49 CFR.

c. A pressure relief valve shall be installed immediately upstream of the GSE/flight hardware interface. Minimum flow and set pressure requirements are as follows:

1. The relieving capacity shall be sufficient to prevent the downstream pressure from exceeding the allowable limits of the flight hardware or 20 percent above the GSE system MOP, whichever is less. **NOTE:** The analysis shall assume that all relief valves connected to the vent system are open and flowing full capacity.

2. The relief valve shall be set to operate no higher than 110 percent of the GSE MOP or the flight hardware pressure limit, whichever is less.

3.11.4.11 Ground Support Hypergolic Propellant System General Relief Devices

a. The flow capacity for all relief devices shall be certified in accordance with ASME Code, Section VIII, Division 1, Paragraphs UG-127, UG-129, UG-131, and UG-132, as applicable.

b. The body and other pressure containing parts for pressure relief devices shall be type 304 or 316 stainless steel.

c. The relief valve outlet piping shall be sized in accordance with ASME VIII, Division 1, UG-135(g). The static back pressure developed at the discharge flange of the relief valve shall be held to within 10 percent of the set pressure of the relief valve.

d. All relief valves and piping shall be structurally restrained to eliminate any thrust effects from transferring moment forces to the vessel nozzles or lines.

e. The effects of the discharge from relief valves shall be assessed and analyzed to ensure that operation of the device will not be hazardous to personnel or equipment. **NOTE:** Items to be analyzed are thrust loads, noise, impingement, and high velocity gas or entrained particles, toxicity, and flammability.

f. No obstructions to flow shall be installed downstream of any relief device except as allowed per ASME Code, Section VIII, Division 1, Appendix M, Paragraph M-6. **NOTE:** Shutoff valves that are permitted shall be permanently marked to identify valve position (OPEN or CLOSED).

g. Pressure relief systems shall be equipped with an isolation valve between the relief valve inlet manifold and the vessel outlet nozzle for inspection and repair purposes. **NOTE**: This valve shall be designed to be locked open.

h. A three-way valve with dual relief valve is required where continuous operation of the system is needed during relief valve calibration.

3.11.4.12 Ground Support Hypergolic Propellant System Vents

a. All hypergolic vent effluent resulting from routine operations shall be scrubbed prior to venting to the atmosphere through vent stacks.

b. GSE that is intended to transfer hypergolic propellants shall be designed to preclude unnecessary liquid traps.

c. All scrubber and incinerator designs and qualification tests shall be reviewed and approved by Range Safety, Bioenvironmental Engineering, and Civil Engineering.

d. Hypergolic systems shall be designed so that pressure cannot be trapped in any part of the system without vent capability.

e. Vent system outlets shall be in a location normally inaccessible to personnel and shall be conspicuously identified.

f. Vent outlets shall be protected against rain intrusion and entry of birds, insects, and animals.

g. Oxidizer and fuel vent outlets to the atmosphere shall be separated sufficiently to prevent mixing of vented fluids.

h. Special attention shall be given to the design of vent line supports at vent outlets due to potential thrust loads. **NOTE:** See ANSI/ASME B31.3, Paragraph 322.6.2.

i. Each line venting into a multiple use vent system shall be protected against back pressurization by means of a check valve if the upstream system cannot withstand the back pressure or where contamination of the upstream system cannot be tolerated.

j. Pressure relief vents shall be designed and located so that vapors will not enter any inhabited areas.

k. Incompatible fluids shall not be discharged into the same vent or drain system.

l. Fuel and oxidizer vent systems shall be equipped with a means of purging the system with an inert gas to prevent explosive mixtures.

m. Vent systems shall be sized to provide minimum back pressures consistent with required venting flow rates. In no case shall back pressures interfere with proper operation of relief devices.

3.11.4.13 Testing Ground Support Hypergolic Propellant System Components Prior To Assembly

a. All permanently installed hypergolic pressure vessels, except DOT vessels, shall be hydrostatically tested in accordance with ASME Code, Section VIII, Division 1, Paragraph UG-99, UG-100 or Division 2, Article T-3 or T-4, as applicable.

b. Hypergolic pressure vessels designed to meet DOT specifications shall undergo qualification and hydrostatic testing in accordance with DOT requirements.

c. All components (not including pressure gauges and transducers and rupture disks) shall be hydrostatically tested to 1.5 times the component MAWP for a minimum of 5 min. **NOTE**: The test shall demonstrate that the components will sustain this test pressure without distortion, damage, or leakage.

d. Both the inlet and outlet sides of relief valves shall be pressure tested. When the discharge side has a lower pressure rating than the inlet side, the inlet and outlet shall be hydrostatically tested independently.

e. All mechanical components such as valves, filters, flex hoses, and piping shall be inspected for external distortion or other evidence of physical damage. Damaged components shall be rejected.

f. Functional and leak tests shall be performed at the component MAWP after completion of hydrostatic tests.

g. Pressure relief valves shall be tested for proper setting prior to installation and periodically thereafter.

h. Pressure gauges and transducers shall be hydrostatically tested to a minimum of 1.5 times the system MOP.

i. Pressure gauges and transducers shall be calibrated prior to installation and periodically thereafter.

j. Components may be hydrostatically tested to 1.5 times the system MOP after installation into a system; however, this approach should be avoided if possible and approved by Range Safety.

k. Pneumatic testing to a pressure level of 1.25 times MAWP is permissible only if hydrostatic testing is impractical, impossible, or will jeopardize the integrity of the system or system component. Prior approval for pneumatic testing at the Ranges shall be obtained from Range Safety.

l. All valves shall be tested for both external and internal leakage at MAWP with a 10 percent/ 90 percent helium/nitrogen mixture.

1. No external leakage is allowed (bubble-tight).

2. Internal leakage of valves shall not exceed limits specified in the valve performance specification.

3. Where no valve specification exists, the leak rate shall not exceed 1 x 10^{-6} cc/sec at standard temperature and pressure.

m. Certain critical system components may require further testing (mass spectrometer) in accordance with ASME Code, Section V, Article 10, Appendix IV or V.

3.11.4.14 Testing Ground Support Hypergolic Propellant Systems After Assembly

3.11.4.14.1 Hydrostatic Tests. All newly assembled hypergolic pressure systems shall be hydrostatically tested to 1.5 times MOP prior to use. **NOTE:** Where this is not possible, Range Safety will determine the adequacy of component testing and alternate means of testing the assembled system.

3.11.4.14.2 Leak Tests.

a. After hydrostatic testing and prior to the introduction of propellant, a pneumatic leak test of completely assembled systems shall be conducted at the system MOP using a 10 percent/90 percent helium/nitrogen mixture.

b. All mechanical joints such as gasket joints, seals, threaded joints, connections, and valve bonnets and weld joints shall be visually bubble tight when tested with leak test solution per MIL-L-25567 Type I or equivalent.

c. The functional capability of isolation valves shall be checked. Isolation valves shall not leak internally in either direction with MOP differential applied.

d. Alternate methods of leak testing such as the use of portable mass spectrometers may be specified when required on a case-by-case basis.

e. Systems designed to meet DOT specifications and regulations shall undergo leak testing in accordance with DOT requirements.

3.11.4.14.3 System Validation Test. All newly assembled hypergolic systems shall have a system validation test (hot flow test) performed at the system MOP prior to first operational use at the Ranges. Minimum test requirements are as follows:

a. As applicable, hypergolic fuels or oxidizers shall be used as the test fluid media.

b. The functional capability of all components and subsystems shall be validated.

c. All operational sequences for the system shall be exercised, including emergency shutdown and safing procedures.

3.11.4.14.4 Grounding and Bonding. All new-ly assembled hypergolic fuel systems shall be test-ed to verify that the bonding and grounding requirements of the **Ground Support Pressure Systems Grounding and Bonding** section of this

Chapter have been met.

3.11.4.15 Periodic Test Requirements for Ground Support Hypergolic Systems

a. Flex hoses shall be hydrostatically tested to 1.5 times their MAWP once a year. *EXCEPTION: This requirement does not apply to flex hoses that are permanently installed, located, and operated in an environment that does not exceed the rated temperature, pressure, and shelf life of the hose.*

b. At least annually, all permanently installed flex hoses shall be visually inspected over their entire length for damaged fittings, broken braid, kinks, flattened areas, or other evidence of degradation.

c. Pressure gauges and transducers shall be calibrated once a year.

d. Pressure relief valves shall be tested for proper setting and operation once a year.

3.11.4.16 Testing Ground Support Modified and Repaired Hypergolic Systems

a. Any hypergolic pressure system or system component, including fittings or welds, that has been repaired, modified, or possibly damaged, subsequent to having been hydrostatically tested, shall be retested hydrostatically to 1.5 times MAWP prior to reuse. **NOTE:** Replacement of gaskets, seals, and valve seats that do not affect the structural integrity does not require a retest.

b. A hypergolic system that has been modified or repaired shall be leak tested at the system MOP before being placed back in service. **NOTE**: This test shall be conducted at the Ranges unless prior approval from Range Safety has been obtained.

c. Modified or repaired hypergolic systems and components shall be functionally tested (re-validated) at the system MOP before being placed back in service.

d. All hypergolic system mechanical joints affected in the disconnection, connection, or replacement of components shall be leak tested at the system MOP before being placed back in service.

3.11.5 Ground Support Cryogenic Systems

This section contains the minimum design requirements for all fixed, mobile, and portable equipment used to handle liquid oxygen (LO_2 or LOX), or liquid hydrogen (LH_2), liquid helium (LHe), liquid nitrogen (LN_2) and their respective vent gases.

3.11.5.1 Ground Support Cryogenic Systems General Design Requirements

a. Cryogenic systems shall be designed to ensure separation of fuels and oxidizers to prevent their mixing due to inadvertent operations.

b. Cryogenic systems shall be provided with readily accessible low point drain capability to allow draining of tanks and piping systems. **NOTE:** Small volumes contained in valves, filters, and other containers that will boil off in a short period of time do not require low point drain capability.

c. Cryogenic fuel and oxidizer systems shall have the capability of loading one commodity at a time.

d. For failure modes that could result in a time-critical emergency, provision shall be made for automatic switching to a safe mode of operation. **NOTE**: Caution and warning signals shall be provided for these time-critical functions.

e. Systems shall be designed so that the system being loaded (flight propulsion systems or propellant tanks) and the propellant loading system can be commonly grounded and bonded during propellant transfer operations. **NOTE:** Loading systems include portable vessels and units.

f. Pneumatic systems servicing fixed, portable, and mobile cryogenic systems shall comply with the requirements of the **Ground Support Pneumatic Systems** section of this Chapter.

g. Cryogenic systems shall be insulated with compatible material or be vacuum-jacketed to avoid liquefaction of air. **NOTE:** Drip pans or other equi-valent means should be provided under flanges when there exists the possibility of leaking liquefied air. Such systems that are not fully insulated and sealed tight or double-walled with a jacket may leak liquefied air.

h. Insulation used in the design of cryogenic systems shall be compatible. **NOTE:** See the **Ground Support Pressure System Material Selection and Compatibility** section of this Chapter for guidance.

i. Vacuum-jacketed systems shall be capable of having the vacuum verified.

j. Purge gas for LH_2 and cold gaseous hydrogen (GH_2) lines shall be gaseous helium (GHe). Neither gaseous nitrogen (GN_2) nor LN_2 shall be introduced into any LH_2 line that interfaces with a liquid storage tank cold port.

k. Precautions shall be taken to prevent cross mixing of media through common purge lines by use of check valves to prevent back flow from a system into a purge distribution manifold.

l. Cross connection of GN_2 and GHe systems is prohibited.

m. Sample ports shall be provided at the system low points.

n. Titanium and titanium alloys shall not be used where exposure to gaseous oxygen (GOX) (cryogenic) or LOX is possible.

3.11.5.2 Mobile and Portable Equipment Used to Transport Cryogenic Fluids

a. Mobile equipment for public and Range highway use shall be designed to meet the requirements of 49 CFR. **NOTE:** A copy of any DOT approved exemptions shall be provided to Range Safety.

b. Portable equipment that is designed for use for storage or transportation of cryogenic fluids shall be designed to meet applicable requirements for packaging set by 49 CFR.

c. The total maximum weight of portable equipment shall meet the Occupational Safety and Health Administration (OSHA) requirements related to permissible weight limit for an individual to transport.

3.11.5.3 Ground Support Cryogenic System Storage Vessels

a. All permanently installed cryogenic vessels shall consist of an inner and an outer shell.

b. The annular space between the inner and outer shell shall be insulated and may be vacuum-jacketed or purged. *EXCEPTION: LH_2 and LHe vessels shall be vacuum-jacketed*.

c. The inner shell shall be designed, constructed, tested, certified, and code stamped on the exterior of the vessel in compliance with ASME, Section VIII, Division 1 or Division 2.

d. In lieu of the code stamp, a nameplate bearing the required inner shell data shall be attached to the outer shell. **NOTE:** An additional nameplate (marked DUPLICATE) may be attached to the support structure.

e. All ASME code stamped vessels shall be registered with the National Board of Boiler and Pressure Vessel Inspectors.

f. The outer shell shall be designed for 0.0 psig internal pressure and 15.0 psig external pressure.

g. For non-vacuum-jacketed vessels, the annular space shall be protected by means of a vacuum breaker.

h. The inner shell and piping in the annular space should be type 304 or 316 (304L or 316L if welded) stainless steel. **NOTE:** The outer shell and supports may be stainless steel or carbon steel.

i. Pressure vessels shall be designed with an opening for inspection purposes.

j. All inner shell pressure retaining welds including shell, head, nozzle, and nozzle to head and shell welds shall be inspected by radiographic and/or ultrasonic volumetric NDE.

k. All inner shell attachment welds for items such as supports, lugs, and pads shall be inspected by liquid penetrant, ultrasonic, magnetic particle, eddy current, and/or radiographic surface NDE.

l. Welded attachments to the inner vessel such as stiffening rings or supports shall be continuously welded.

m. All attachments to the inner shell shall be positioned so that no attachment weld overlaps any Category A or B weld as defined in ASME Code, Section VIII, Division 1, Paragraph UW-3.

n. Local and remote readout liquid level indicators shall be provided for LH_2 and LO_2 storage vessels.

o. At a minimum, local readout capability shall be provided for all other cryogenic storage vessels.

p. Portable and mobile cryogenic storage vessels used for transportation shall be designed, fabricated, inspected, and tested in accordance with 49 CFR.

3.11.5.4 Ground Support Cryogenic System Piping

3.11.5.4.1 Piping Design, Insulation, and Material.

a. All cryogenic piping shall be designed in accordance with ANSI/ASME B31.3.

b. Vacuum-jacketed or other types of thermal insulation shall be based on system heat leak rate and failure mode and effect determination.

c. Gasket material used in LH_2 transfer piping flanged joints shall be glass-filled 3/32-in. thick Teflon. **NOTE**: Recommended materials may be obtained from the following companies: Garlock 8573, Garlock, Inc., Palmyra, NY; Fluorgold, Fluorocarbon Co., Anaheim, CA; and Fluorogreen E-600, Peabody Company, (Peabody-Dore Co.), Houston, TX.

d. Gaskets shall not be reused.

3.11.5.4.2 Piping System Joints, Connections,

and Fittings.

a. Joints in piping systems shall be of the butt weld, flanged, bayonet, or hub type in accordance with KSC-GP-425, KC159/KC163, or the commercial equivalent.

b. Butt welded joint designs shall meet the requirements of ANSI B16.9.

c. Flanged joints shall be either weld neck or lap joint, raised face type conforming to ANSI B16.5, and shall be constructed of forged ASTM A182 type 304L or 316L material. **NOTE**: The use of slip-on flanges shall be avoided.

d. Flange faces or lap-joint stub end faces shall be concentrically serrations conforming to MSS-SP-6.

e. LH_2 vent system flanged joints shall be metal-to-metal and shall be seal-welded unless otherwise approved by Range Safety.

f. Flange bolting and studs shall conform to ANSI/ASME B18.2.1 recommended dimensions and shall use ANSI/ASME B1.1 threads.

g. Bolt materials shall be per ASTM A193 or ASTM A320.

h. Nuts for flange bolting and studs shall conform to ANSI/ASME B18.2.2 heavy hex type per ASTM A194 (type 304 stainless steel) or ASTM A194 (type 316 stainless steel) and shall use ANSI/ASME B1.1 threads.

i. Pipe fittings such as tees, elbows, crosses, re-ducers, and lap joint stub ends shall be butt welded only conforming to ANSI/ASME B16.9 and shall be type WP-304L or WP-316 material in accordance with ASTM A 403.

j. Bayonet fittings shall be used on vacuum-jacketed lines where butt welding is not practical and a mechanical joint is required.

k. Metal-to-metal couplings shall be the butt welded type. **NOTE**: The gaskets (not reusable) should be constructed of stainless steel only. The V-band clamps should be constructed of stress-corrosion-resistant material.

3.11.5.4.3 Non-Vacuum-Jacketed Cryogenic Piping. All non-vacuum-jacketed cryogenic piping shall conform to ANSI B36.19M and shall be seamless, type 304L or 316L material in accordance with ASTM A 312.

3.11.5.4.4 Vacuum-Jacketed Piping.

a. Vacuum-jacketed pipe may have an inner pipe of Invar 36 or NILO 36 or type 304L or 316L material meeting the above requirements for stainless steel piping. The outer jacket shall be type 304L or 316L material.

b. Vacuum-jacketed pipe should not use bellows in the inner pipe. Allowance for differential expansion between inner and outer pipe shall be provided by bellows in the outer pipe.

3.11.5.4.5 Thermal Expansion and Contraction. Cryogenic piping systems shall provide for thermal expansion and contraction without imposing excessive loads on the system. **NOTE**: Offset bends and loops rather than bellows should be used for this purpose wherever possible.

3.11.5.4.6 Cryogenic Pipe Weld Inspection.

a. All inner pipe welds shall be 100 percent radiographically inspected.

b. The accept and reject criteria shall be in accordance with Table 341.3.2A of ANSI/ASME B31.3.

3.11.5.5 Ground Support Cryogenic System Valves

a. Inlet and outlet isolation valves and appropriate intermediate vent valves shall be provided for shutdown and maintenance.

b. Systems shall have shutoff valves located as close to the supply vessel as practicable and be readily accessible.

c. Cryogenic systems shall be designed to ensure icing does not render the valve inoperable.

d. Remotely controlled valves shall provide the remote monitoring of OPEN and CLOSED positions.

e. Remotely operated valves shall be designed to be fail-safe if pneumatic or electric control power is lost. **NOTE**: Fail-safe criteria (fail-open or fail-close) shall be determined on a case-by-case basis.

f. All electrical control circuits for remotely actuated valves shall be shielded or otherwise protected from hazardous stray energy.

g. Gate valves shall be designed with the volume between the valve discs and the trapped volume in the bonnet vented upstream.

h. Manually operated valves shall be designed so that overtorquing the valve stem cannot damage seats to the extent that seat failure occurs.

i. Designs using uncontained seats are prohibited.

j. Valve stem travel shall be limited by a positive stop at each extreme position.

k. The application or removal of force to the valve stem positioning device shall not cause disassembly of the pressure containing structure of the valve.

l. Manual and remotely controlled valve actuators shall be capable of completely opening or closing shutoff valves under maximum possible pressure and flow conditions in the system.

m. Cryogenic valves with extended stems shall be installed with the actuator approximately vertical above the valve.

n. Valves that are not intended to be reversible shall be designed or marked so that they will not be connected in a reverse mode.

o. All valves should be fabricated from Type 304 or 316 stainless steel (type 304L or 316L if welded) with minimum wall thickness equivalent to Schedule 10 pipe.

p. Design of the valve jacket shall not adversely affect the function or maintainability of the valve.

q. Local or remote stem position indicators shall sense the position of the stem directly, not the position of the actuating device.

3.11.5.6 Ground Support Cryogenic System Pressure Indicating Devices

a. A pressure indicating device shall be located on any storage system and on any section of the system where pressure can be trapped.

b. As determined by Range Safety, remote readout pressure transducers are required when it is necessary to monitor hazardous operations from a remote location.

c. Gauges shall be selected so that the normal operating pressure falls between 25 percent and 75 percent of the scale range, except for gauges used in applications that require a very wide range of operating pressure. For these applications, the pressure gauges shall be selected so that the maximum pressure that can be applied shall not exceed 95 percent of the scale range of the gauge.

d. Pressure gauges shall be of one piece, solid front, metal case construction, using an optically clear shatterproof window made of high-impact, non-cracking plastic, heat-treated glass, or laminated glass.

e. Pressure gauges shall be equipped with a full-diameter pressure release back capable of accommodating maximum flow without rupturing the case. **NOTE**: The use of blowout plugs is not recommended.

f. All pressure gauge material normally in contact with the service fluid should be type 316 stainless steel.

g. If pressure gauge isolation valves are used, they shall be designed so that they can be lockwired in the OPEN position.

h. The operating range of pressure transducers used for monitoring pressures during hazardous operations shall not be less than 1.2 and not more than 2.0 times the system MOP.

i. Gauge installations shall be designed to have a minimum 1-in. clearance in back to provide unrestricted venting.

j. Personnel and critical equipment shall be protected from potential venting hazards.

3.11.5.7 Ground Support Cryogenic System Flexible Hoses

a. Flexible (flex) hoses shall be used only when required to isolate vibration and piping movement and for hookup of portable and mobile equipment.

b. Flexible hoses shall be of the single-wall, double-wall, or double-wall vacuum-jacketed type.

c. All convoluted portions of flexible hoses shall be covered with stainless steel wire braid.

d. Flex hose installation shall be designed to avoid abrasive contact with adjacent structures or moving parts.

e. Flex hose assemblies shall not be installed in a manner that will place a mechanical load on the hose or hose fittings to an extent that will degrade hose strength or cause the hose fitting to loosen.

f. Flexible hose shall not be supported by rigid lines or components if excessive loads from flex hose motion can occur.

g. Flexible hose between two components may have excessive motion restrained where necessary but shall never be rigidly supported by a tight rigid clamp around the flexible hose.

h. The bend radius of flex hoses shall be designed to be no less than the safe minimum bend radius recommended in authoritative specifications for the particular hose and in no case less than 5 times the outside diameter of the hose.

i. A means of plugging or capping flex hoses shall be provided when they are not in use.

j. All flexible hoses that are not lined shall be subjected to a flow induced vibration analysis. **NOTE:** A guidance document for performing this analysis is MSFC 20MO2540.

3.11.5.8 Ground Support Cryogenic System Pressure Relief Devices

a. All fixed cryogenic storage vessels shall be protected from overpressure by means of at least one spring-loaded or pilot-operated relief valve. **NOTE**: Required relief capacity should be provided by means of a single relief valve, if possible.

1. A rupture disc may be installed in series with the relief valve to prevent loss of hazardous fluids, provided that the limitations of ASME Code, Section VIII, Division 1, Paragraphs UG-127(a)(3)(b) and UG-127(a)(3)(c) or Division 2, Article R-1, Paragraphs AR-131.4 and AR-131.5 are met.

2. The space between the rupture disc and the relief valve shall be designed so that it can be tested at least annually for leakage past the rupture diaphragm.

3. Rupture discs in systems containing reactant fluids shall be replaced every two years or sooner based on manufacturer recommendations. **NOTE:** Providing a screen between the rupture disc and the valve to prevent rupture disc contamination of the relief valve should be considered.

4. Installation of pressure relief devices shall be in accordance with ASME Code, Section VIII, Division 1, Paragraph UG-135 or Division 2, Article R-1.

5. The total relieving capacity required shall be determined in accordance with ASME Code, Section VIII, Division 1, Paragraph UG-133 or Division 1, Paragraph AR 150 as applicable.

6. The primary relief device shall be set at a pressure not to exceed the MAWP of the cryogenic storage vessel. (See ASME Code, Section VIII, Division 1, Paragraphs UG-134 or Division 2, Article R-3, Paragraph AR-140 for pressure setting and tolerance requirements.)

b. DOT vessels shall be protected against overpressure in accordance with 49 CFR.

c. Pressure relief devices shall be provided in each segment of a system where a cryogenic liquid can be trapped. The flow and set pressure requirements for these relief valves are as follows:

1. The relief valve capacity shall prevent the pressure from rising more than 20 percent above the system MOP or that allowed by ANSI/ASME B31.3, whichever is less.

2. The relief valve shall be set to operate at a pressure not to exceed 110 percent of the system MOP or that allowed by ANSI/ASME B31.3, whichever is less.

d. Ground Support Cryogenic System General Relief Devices

1. The flow capacity for all relief devices shall be certified in accordance with ASME Code, Section VIII, Division 1, Paragraphs UG-127, UG-129, UG-131 and UG-132, as applicable.

2. The body and other pressure containing parts for pressure relief devices should be type 304 or 316 (or 304L or 316L if welded) stainless steel.

3. Pressure system relief devices shall have no intervening stop valves between piping being protected and the relief devices or between the relief device and the point of discharge except as allowed by ANSI/ASME B31.3, Paragraph 322.6.1.

4. When a shutoff valve is allowed in accordance with the ANSI or ASME Code, the valve type shall have provisions for being safety wired in the OPEN or CLOSED position. **NOTE**: The valve shall have permanent marking clearly identifying its position (OPEN or CLOSED).

5. The relief valve outlet piping shall be sized in accordance with ASME VIII, Division 1, UG-135(g). **NOTE:** The static back pressure developed at the discharge flange of the relief valve shall be held to within 10 percent of the set pressure of the relief valve.

6. All relief valve installations shall be designed to withstand reaction loads due to operation of the relief valve.

7. The effects of the discharge from relief devices shall be assessed and analyzed to ensure that operation of the device will not be hazardous to personnel or equipment. Items to be analyzed are thrust loads, noise impingement of high velocity gas or entrained particles, toxicity, oxygen enrichment, flammability, and oxygen deprivation.

8. No obstructions to flow shall be placed downstream of any relief device except as allowed per ASME Code, Section VIII, Division 1, Appendix M, Paragraph M-6 or ASME B31.3, Paragraph 322.6.1.

3.11.5.9 Ground Support Cryogenic System Vents

a. GH_2 shall be vented to the atmosphere through a burner system unless otherwise agreed to by Range Safety.

b. GH_2 burner design and testing requirements shall be approved by Range Safety.

c. Cryogenic systems shall be designed so that fluids cannot be trapped in any part of the system without drain or vent (relief valve or vent valve) capability.

d. Each line venting into a multiple use vent system shall be protected against back pressurization by means of a check valve if the upstream system cannot withstand the back pressure or where contamination of the upstream system cannot be tolerated.

e. Vent systems shall be sized to provide minimum back pressures consistent with required venting flow rates. **NOTE:** In no case shall back pressures interfere with proper operation of relief devices.

f. Vents shall be placed in a location normally inaccessible to personnel and at a height or location where venting will not normally be deposited into habitable spaces.

g. Each vent shall be conspicuously identified using appropriate warning signs, labels, and markings.

h. Vent outlets shall be located far enough away from incompatible propellant systems and incompatible materials to ensure no contact is made during vent operations.

i. Incompatible fluids shall not be discharged into the same vent or drain system.

j. Vent outlets shall be protected against rain intrusion and entry of birds, insects, and animals.

k. All vent line supports shall be designed to withstand reaction loads due to actuation of safety relief devices. (See ANSI/ASME B31.3, Paragraph 322.6.2.)

l. Fuel and oxidizer vent systems shall be equipped with a means of purging the system with an inert gas to prevent explosive mixture.

3.11.5.10 Testing Ground Support Cryogenic Systems Prior to Assembly

a. All permanently installed cryogenic storage vessels except DOT vessels shall be hydrostatically tested in accordance with ASME Code, Section VIII, Division 1, Paragraphs UG-99 and UG-100 or Division 2, Article T-3 or T-4, as applicable.

b. Vessels designed to meet DOT specifications and regulations shall undergo qualification and hydrostatic testing in accordance with DOT requirements.

c. All components such as valves, filters, pipes, pipe fittings, and hoses (not including pressure gauges, transducers, and rupture disks) shall be hydrostatically tested to a minimum of 1.5 times the component MAWP at ambient temperature for a minimum of 5 min to demonstrate that the components will sustain test pressure levels without distortion, damage, or leakage.

d. All mechanical components such as valves, regulators, filters, piping, and hoses shall be inspected for distortion or other evidence of physical damage. **NOTE**: Damaged components shall be rejected.

e. Functional and leak tests shall be performed at the component MAWP after the hydrostatic tests.

f. Both the inlet and outlet sides of a relief valve shall be pressure tested. When the discharge side has a lower pressure rating than the inlet side, the inlet side and the outlet side shall be tested independently.

g. Pressure relief valves shall be tested for proper setting prior to installation and periodically thereafter.

h. Pressure gauges and transducers shall be hydrostatically tested to a minimum of 1.5 times the system MOP.

i. Pressure gauges and transducers shall be calibrated prior to installation and periodically thereafter.

j. Pneumatic testing to a pressure level of 1.25 times MAWP is permissible only if hydrostatic testing is impractical, impossible, or will jeopardize the integrity of the system or system element. **NOTE:** Prior approval for pneumatic testing at the Ranges shall be obtained from Range Safety.

3.11.5.11 Testing Ground Support Cryogenic Systems After Assembly

3.11.5.11.1 Hydrostatic Tests.

a. All cryogenic systems shall be hydrostatically tested to at least 1.25 times system MOP using an inert cryogenic fluid at or below the expected lowest temperature.

b. Cryogenic systems that cannot be chilled and hydrostatically tested with an inert fluid at or below the lowest expected temperature will require both a cold shock demonstration test and analysis (a hazard analysis and a fracture mechanics safe-life analysis in accordance with Appendix 3C) approved by Range Safety.

c. The hydrostatic test or cold shock/soak test (for at least 1 h) shall demonstrate that the system or components will sustain test pressure level and temperature gradient without distortion, damage, or leakage.

3.11.5.11.2 Inspections for Vacuum-Jacketed Systems. In addition to the hydrostatic test requirements stated above, the following inspections shall be performed on vacuum-jacketed systems:

a. An examination for cold spots on vacuum jackets. **NOTE:** Cold spots in the outer line shall not be 5°C colder than the surrounding area, except in cases where system heat-leak requirements permit colder temperatures, such as around low-point drain valves, relief valves, or other areas where a direct thermal path is available.

b. Vacuum readings for all vacuum volumes shall be taken and recorded. **NOTE:** These readings shall be taken before, during, and after the test.

c. The vacuum readings after the hydrostatic or cold shock/soak using a cryogenic fluid shall be taken when the system returns to ambient temperature.

3.11.5.11.3 Pneumatic Leak Test.

a. After successful completion of the hydrostatic test using a cryogenic fluid, a pneumatic leak test of the complete system shall be performed at the system MOP using helium or a mixture of nitrogen with a minimum of 25 percent helium.

b. There shall be no leakage into the vacuum volume in excess of 10^{-6} cc/sec. **NOTE**: The sensitivity of the instrumentation used to measure leak rate shall be a minimum of 1 times 10^{-9} std cm^3/sec/div in accordance with article 10 of the ASME Code.

c. All pressure boundary welds and mechanical points such as gasket joints, seals, threaded connections, and valve bonnets shall be visually bubble tight during the leak test.

3.11.5.11.4 System Validation Test. Following the leak test, all newly assembled cryogenic systems shall have a system validation test performed at MOP prior to first operational use at the Ranges. Minimum test requirements are as follows:

a. The intended service fluid (LO_2, LH_2, LN_2, LHe) shall be used as the test fluid.

b. The functional capability of all components and subsystems shall be validated.

c. All operational sequences for the system shall be exercised, including emergency shutdown/safing and unloading procedures.

d. All newly assembled cryogenic systems shall be tested to verify that the bonding and grounding requirements of the **Ground Support Pressure System Bonding and Grounding** section of this Chapter have been met.

3.11.5.12 Ground Support Cryogenic Systems Periodic Tests

a. Flex hoses shall be hydrostatically proof tested to 1.5 times their MAWP once a year unless otherwise approved by Range Safety.

b. Pressure gauges and transducers shall be calibrated once a year.

c. Pressure relief valves shall be tested for proper setting and operation once a year.

3.11.5.13 Testing Modified and Repaired Ground Support Cryogenic Systems Tests

a. Any cryogenic system component, including fittings or welds, that has been modified or repaired shall be tested prior to reuse.

b. Components that are modified or repaired in any way shall be pressure tested prior to reuse.

c. The component retest sequence shall be as follows unless otherwise approved by Range Safety:

1. The component shall be hydrostatically tested to 1.5 times the components MAWP. **NOTE:** The fluid shall be at ambient temperature.

2. A hydrostatic test using an inert cryogenic fluid at or below the expected lowest temperature shall be performed in the same manner as described in section 3.11.5.11.1 above.

3. The component shall be reinstalled in the system and a leak test performed in the same manner as described in section 3.11.5.11.3 above.

d. All cryogenic system mechanical joints affected in disconnection, connection, or replacement of components shall be pneumatically leak tested at the system MOP prior to being placed back in service. **NOTE**: This test shall be conducted as described in section 3.11.5.11.3 above.

3.11.6 Ground Support Pressure Systems Data Requirements

This section lists the minimum data required to certify compliance with the design, analysis, and test requirements of the **Ground Support Pressure Systems** section of this Chapter. Data required by paragraphs 3.11.6.1 through 3.11.6.4 in this section shall be incorporated into the MSPSP or submitted as a separate package when appropriate. Data required by paragraph 3.11.6.5 shall be placed in a certification file to be maintained by the hazardous pressure system operator. This data shall be reviewed and approved by Range Safety prior to first operational use of hazardous pressure systems at the Ranges.

3.11.6.1 Ground Support Pressure Systems General Data Requirements

The following general ground support equipment data is required in the MSPSP (See Appendix 3A.):

a. Hazard analysis of hazardous pressure systems in accordance with a jointly tailored System Safety Program Plan (Chapter 1, Appendix 1B.).

b. A compliance checklist of all design, test, analysis, and data submittal requirements in this Chapter.

c. The material compatibility analysis in accordance with the **Ground Support Pressure System Material Selection and Compatibility** section of this Chapter.

d. Inservice operating, maintenance, and inspection plan in accordance with the **Inservice Operating, Maintenance, and Inspection Plan** section of this Chapter.

e. Physical and chemical properties and general characteristics of the propellant, test fluid, and gases. **NOTE:** Data shall be provided to Range Safety, Bioenvironmental Engineering, Bioenvironmental Planning, 30 CEG, and 30 SW/ET, as applicable.

f. For hazardous propellants, fluids, and gases, the following data shall be submitted:

1. Specific health hazards such as toxicity and physiological effects

2. Threshold Limit Values (TLV), maximum allowable concentration (MAC) for 8-hr day, 5-day week of continuous exposure

3. Emergency tolerance limits including length of time of exposure and authority for limits, such as the Surgeon General, National Institute of Occupational Safety and Health (NIOSH), and independent study

4. Maximum credible spill (volume and surface area) and supporting analysis.

5. Description of hazards other than toxicity, such as flammability and reactivity

6. Identification of material incompatibility problems in the event of a spill

7. Personal protective equipment to be used in handling and using propellants, when this equipment will be used during an operation, and manufacturer, model number, and other identifying data

8. Manufacturer, model number, specifications, operating limits, type of certification, and general description of vapor detecting equipment

9. Recommended methods and techniques for decontamination of areas affected by spills or vapor clouds and hazardous waste disposal procedures

3.11.6.2 Ground Support Pressure Systems Design Data Requirements

a. A copy of any DOT approved exemptions for mobile and portable hazardous pressure systems shall be submitted to Range Safety.

b. A schematic that presents the system in a clear and easily readable form, with complete subsystems grouped and labeled accordingly; nomenclature of each element should be made adjacent to or in the vicinity of each element. The schematic or corresponding data sheet shall contain the following information:

1. Identification of all pressure system components such as valves, regulator, tubes, hoses, vessels, and gauges using standard symbols. **NOTE:** A legend is recommended and the original mechanical drawings should be referenced

2. MOP of all systems and subsystems at expected operating temperatures and identification of expected source pressures and expected delivery pressures

3. All relief valve pressure settings and flow rates

4. System fluid and maximum expected temperature

5. Pressure ranges of all pressure gauges

6. Pressure settings of pressure regulators

7. Charging pressure of reservoirs and vessels, their nominal capacities, and wall thickness

8. Pressure setting of all pressure switches

9. Nominal outside diameter and wall thickness of all tubing

10. Flowpath through all components. **NOTE:** When the system is to be used in several operating modes, it is easier to provide a separate schematic that shows flowpaths for each operating mode.

11. Identification of each component (reference designations) so that cross-reference between schematics and drawings and a pressure system component list or other documentation is possible

12. End-to-end electrical schematics of electrical and electronic components giving full functional data and current loads

13. Connections for testing or servicing

14. A narrative that provides the following information:

(a) Description of the system and its operating modes

(b) Discussion of operational hazards

(c) Discussion of accessibility of components

15. A sketch or drawing of the system that shows physical layout and dimensions

16. System information shall be placed in tables (See Appendix 3A for guidance.)

3.11.6.3 Ground Support Pressure Systems Component Design Data

a. Identification of each component with a reference designation permitting cross-reference with the system schematic

b. MAWP for all pressure system components and the MOP the component shall see when installed in the system

c. Safety factors or design burst pressure for all pressure system components and identification of actual burst pressures, if available

d. Hydrostatic test pressure for each system component and identification of the test pressure the component will see after installation in the system, if applicable

e. Materials used in the fabrication of each element in the components, including soft goods and other internal elements

f. Cycle limits if fatigue is a factor of the component

g. Temperature limits of each system component

h. Manufacturer name, model number, and part number of all components

i. Component information should be placed in tables (See Appendix 3A for guidance.)

3.11.6.4 Ground Support Pressure Systems Test Procedures and Reports

a. All test plans, test procedures and test reports required to be performed by the **Ground Support Pressure Systems** section of this Chapter shall be submitted to Range Safety for review and approval.

b. A list and synopsis of all hazardous pressure system operational procedures to be performed at the Ranges shall be provided.

3.11.6.5 Ground Support Pressure Systems Certification Files

3.11.6.5.1 Ground Support Pressure Systems Certification Files General Requirements.

a. Certification files shall be maintained and updated by the hazardous pressure system operator. **NOTE 1**: These files shall be located at the Range User facility at the Ranges. **NOTE 2**: Vessels and systems, including mobile and portable systems, that do not have current certification files may be deactivated and removed from service by Range Safety.

b. Certification files shall be updated within 90 calendar days of completion of periodic inspections and tests.

c. Updated information shall include any changes to the current certification files and the following:

1. Temperature, pressurization history, and pressurizing fluid for both the tests and operations

2. Results of any inspection conducted, including the name of the inspector, inspection dates, inspection techniques used, location and character of defects, defect origin, and defect cause

3. Maintenance and corrective actions performed from the time of manufacture throughout operational life, including refurbishment

4. Sketches and photographs to show areas of structural damage and extent of repairs

5. Certification and recertification tests performed, including test conditions and results

6. Analysis records and drawings supporting the repair or modification

3.11.6.5.2 Ground Support Pressure Systems Certification Data.

a. The certification file for each hazardous pressure system shall contain the data required in sections 3.11.6.1, 3.11.6.2, 3.11.6.3, and 3.11.6.4 of this Chapter.

b. The following data shall also be included:

1. Design calculations for stress, fatigue, and other items that verify compliance with applicable code requirements such as ASME, ANSI, and DOT

2. Structural load analysis for hazardous pressure systems exposed to severe launch environments such as vibration, shock, and temperature

3. In-process fabrication and construction inspection plans and results

4. Pressure vessel manufacturer data reports

5. Specification drawings and documents for all components

6. If available, maintenance manuals for all components

7. If available, component operating manual.

8. As required, a cross-sectional assembly drawing of the component to assess the safety aspects of the internal elements

9. System operating and maintenance plans and procedures

10. Certification that welding and weld NDE meet applicable standards such as ASME and ANSI

11. Unique qualification and acceptance test plans and test reports

12. Certification documentation showing that vessels are designed, fabricated, and tested in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1/Division 2 or 49 CFR

13. Certification that all components, including pipe and tube fittings have successfully passed a hydrostatic test

3.11.7 Ground Support Pressure Systems Recertification

3.11.7.1 Ground Support Pressure Systems General Recertification Requirements

a. Guidance for performing recertification can be found in ESMC TR-88-01

b. The recertification period for vessels and systems shall not exceed the shortest period resulting from or determined by the following criteria:

1. The shortest service life determined based on an assessment of inservice failure mechanisms in accordance with paragraph 3.11.1.14.

2. Twenty years for systems and for vessels that can be 100 percent inspected both internally and externally

3. Ten years for systems and for vessels that cannot be 100 percent inspected internally but can be 100 percent inspected externally

4. Five years for systems and for vessels that cannot be 100 percent inspected either internally or externally

5. Manufacturer recommendations

c. All fixed hazardous pressure vessels shall also be recertified when one or more of the following changes or conditions occur:

1. The vessel is planned for service at higher or lower temperatures than those of the previous certification and/or recertification

2. The vessel was removed from service and deactivated without protection from environmental effects; for example, a vessel is not stored inside an environmentally controlled building and does not have a positive internal pressure

3. The vessel was relocated from another installation, agency, or source

4. There is a change of service or commodity, resulting in a new or a change in failure mechanisms

5. The vessel was repaired or modified

6. The vessel has reached the end of its certification or recertification period

d. Portable or mobile vessels and packaging used for transportation of pressurized or hazardous commodities shall be designed, maintained, and recertified in accordance with 49 CFR. **NOTE**: If a DOT vessel is installed on a permanent basis, it shall fall under the recertification requirement for a fixed system.

e. Periodic inspections shall be performed on hazardous pressure systems in accordance with the ISI Plan (See the **Inservice Operating, Maintenance, and Inspection Plan** section of this Chapter). These inspections shall be performed during the following periods:

1. From initial operational use of the vessel and/or system until the vessel and/or system requires recertification. (Called *certification period*)

2. Period from first recertification effort until second recertification. (Called *first recertification period*)

3. All subsequent recertification periods

f. The hazardous pressure system operator shall retain all documentation generated as a result of the recertification effort and place this documentation in the system certification and recertification file located at the Ranges.

3.11.7.2 Ground Support Systems Engineering Assessment and Analysis

3.11.7.2.1 Ground Support Systems Engineering Assessment and Analysis General Requirements.

a. An engineering assessment and analysis shall be performed prior to the start of the first recertification period.

b. The engineering assessment of the design, fabrication, material, service, inspection, and testing shall be evaluated against the latest codes, standards, regulations, and requirements identified in this Chapter.

c. Discrepancies with the latest requirements shall be resolved by repair, modification, analysis, inspection, or test.

3.11.7.2.2 Design, Fabrication, and Installation Deficiencies. At a minimum, the following potential design, fabrication and installation type deficiencies shall be assessed:

a. Design deficiencies such as design notches, weld joint design, and reinforcements

b. Material deficiencies such as laminations, laps, seams, cracks, hardness variations, and notch brittleness

c. Welding deficiencies such as cracks, incomplete fusion, lack of penetration, overlap, undercut, arc strikes, porosity, slag inclusions, weld spatter, residual stresses, and distortion

d. Installation deficiencies such as fit-up, alignment, attachments, and supports

3.11.7.2.3 Operation and Maintenance Deficiencies. At a minimum, the following potential operation and maintenance deficiencies shall be assessed:

a. Refurbishment damage

b. Modification and/or repair deficiencies

c. Operation beyond allowable limits or improper sequence

d. Maintenance deficiencies

3.11.7.2.4 Analysis Methodology. An engineering analysis shall be performed as follows:

a. A stress analysis of all vessels and piping shall be available for evaluation or performed to verify that stresses are within allowable limits of current codes, standards, and regulations as identified in this Chapter.

b. The number of stress cycles experienced by the vessel during the certification period shall be determined.

c. Using fracture mechanics analysis, the cyclic limits for vessels with pressures greater than 2500 psig, burst before leak failure mode, or corrosive and/or toxic fluids shall be determined.

d. The safe-life analysis shall be performed under the assumption of pre-existing cracks. **NOTE**: This does not imply that cracks are allowed. All unacceptable indications shall be repaired. The safe-life analysis shall be conducted in accordance with the following requirements:

1. The analysis shall show that the vessel will service at least four times the cycles expected during the recertification period.

2. The analysis shall calculate and evaluate the results from the worst combination of crack sizes (refer to MSFC-STD-1249 for guidance) and location such as boss transition area, heat affected area, weld joint, and membrane section within the vessel.

3. The appropriate stress component in the vessel shall be used in the analysis.

4. The initial flaw size shall be based on the recertification hydrostatic test pressure to NDE (Refer to MSFC-STD-1249 for guidance).

5. Calculated cycles to failure shall be based on the maximum and minimum operating pressure.

6. A liner elastic fracture mechanic parameter (stress-intensity factors) shall be used to determine critical crack sizes. **NOTE**: The most conservative deformation mode shall be used to determine the appropriate stress-intensity factors (fracture toughness) as appropriate for the parent, weld, and joint materials.

7. Fracture mechanics shall only be used to predict the sub-critical crack propagation life prior to unstable crack growth.

8. The safe-life analysis results shall be reduced by a factor of four in conjunction with assuming the most conservative bounds on material properties and crack growth data for the vessel environment.

9. Failure mode determination shall be in accordance with Appendix 3C.

10. Vessels subject to stress corrosion (sustained stress) shall show that the corresponding applied stress intensity during operation is less than the threshold stress intensity in the intended environment.

11. Corrosion allowance and the remaining wall shall be determined based on MIL-HDBK-729.

3.11.7.2.5 Ground Support Pressure Systems Recertification Test Requirements. Testing requirements for recertification of components and systems are as follows:

a. Vessels and packaging designed to 49 CFR specification shall be retested to DOT requirements.

b. All systems shall be hydrostatically tested at ambient temperatures to 150 percent of the system MOP.

c. Vessels designed to ASME Section VIII, Division 2 that are prohibited from hydrostatic testing to 150 percent of the MOP shall be hydrostatically tested to 125 percent of system MOP at a minimum.

d. Cryogenic systems shall be retested in accordance with the **Testing Ground Support Cryogenic Systems After Assembly** section of this Chapter.

e. 100 percent visual inspection of all joints and connections shall be performed before and after hydrostatic tests. **NOTE**: Parts that indicate a change in volume, permanent deformation, leakages, or cracks shall be rejected.

f. 100 percent visual inspection of the external surfaces of a vessel and system and 100 percent of the internal surfaces for vessels shall be performed.

1. Any sign of corrosion, dents, or other damages shall be identified and annotated on permanently maintained recertification documents.

2. For corroded areas, the corrosion shall be removed.

3. Using Ultrasonic Testing (UT), the entire surface area affected by corrosion shall be measured and the remaining wall thickness determined.

4. Wall areas that are below the minimum required thickness and other unacceptable findings shall be fixed prior to placing the system back into service.

5. The susceptibility effects of corrosion such as cracking, delamination, or intergranular attack should be addressed.

g. All weld joints on vessels and systems with pressure greater than 500 psig or containing a hazardous fluid shall be 100 percent volumetrically and surface inspected.

1. Radiographic examination shall be used to the maximum extent possible.

2. UT shall be used if Radiographic Testing (RT) is determined to be ineffective.

3. Surface and volumetric testing shall be performed after the hydrostatic test only.

h. All components and systems shall be leak checked and functionally tested.

i. Leaks shall be repaired and components that do not function properly shall be repaired or replaced prior to starting the subsequent recertification period.

3.12 FLIGHT HARDWARE PRESSURE SYSTEMS AND PRESSURIZED STRUCTURES

This section establishes minimum design, fabrication, installation, testing, inspection, certification, and data requirements for flight aerospace vehicle equipment (AVE) and pressurized structures. All criteria are mandatory unless tailored by Range Safety for specific applicability for the projected design. **NOTE:** The term *hydraulics* as used in this section does not include cryogenic fluids or fluids considered hazardous as described in the paragraph below.

3.12.1 Flight Hardware Pressure Systems and Pressurized Structures General Requirements

Hazardous flight hardware pressure systems are defined as follows: (1) flight systems containing hazardous fluids such as cryogens, flammables, combustibles, and toxics; (2) systems used to transfer hazardous fluids such as cryogens, flammables, combustibles, and hypergols; (3) systems with operating pressures that exceed 100 psig; (4) systems with stored energy levels exceeding 14,240 ft lb; and (5) systems that are identified by Range Safety as safety critical.

3.12.1.1 Flight Hardware Pressure Vessels, Systems, and Pressurized Structures General Requirements

a. The structural design of all pressure vessels and pressurized structures shall employ proven processes and procedures for manufacture and repair.

b. The design shall emphasize the need for access, inspection, service, repair, and refurbishment.

c. For all reusable pressure vessels and pressurized structures, the design shall permit these hardware to be maintained in and refurbished to a flightworthy condition.

d. Repaired and refurbished hardware shall meet the same conditions of flightworthiness as new hardware.

3.12.1.2 Flight Hardware Pressure Systems Fault Tolerance

a. Airborne hazardous pressure systems shall be designed to be single fault tolerant against inadvertent actuations that could result in a critical hazard during prelaunch operations. **NOTE:**

Structural failure of tubing, piping, and vessels are not to be considered single failures.

b. A pressure system shall be dual fault tolerant if the failure of two components could result in a catastrophic hazard.

3.12.1.3 Flight Hardware Pressure System Offloading

a. Hazardous pressure systems shall be designed so that depressurization and drain fittings are accessible and do not create a personnel or equipment hazard for off-loading hazardous fluids at the launch complex. **NOTE**: This requirement is intended for contingency safing operations.

b. The design goal is to be able to offload these pressure systems at any point after pressurization or loading, including the ability to offload all systems at the launch pad without demating of the spacecraft from the launch vehicle or any other disassembly of vehicle systems.

c. In cases in which the Range User and Range Safety decide that design prohibits offload capability of a mated spacecraft at the launch pad, offload shall be possible within the launch complex.

3.12.1.4 Flight Hardware Pressure Systems Operations

The requirements for operating hazardous pressure systems found in Chapter 6 of this document shall be taken into consideration in the design and testing of these systems in addition to the general requirements identified in paragraph 3.12.5.

3.12.1.5 Flight Hardware Pressure Systems and Pressurized Structures Analyses

3.12.1.5.1 Flight Hardware Pressure System Hazard Analysis.

a. A hazard analysis shall be performed on all hazardous systems hardware and software (if applicable) in accordance with a jointly tailored System Safety Program Plan (Appendix 1B)

b. Prelaunch and launch hazards shall be analyzed.

3.12.1.5.2 Flight Hardware Pressures Systems Functional Analysis. A detailed system functional analysis shall be performed to determine that the operation, interaction, or sequencing of components shall not lead to damage to the launch vehicle, payload, or associated ground support equipment.

a. The analysis shall identify all possible malfunctions or personnel errors in the operation of any component that may create conditions leading to an unacceptable risk to operating personnel or equipment.

b. The analysis shall also evaluate any secondary or subsequent occurrence, failure, or component malfunction that, initiated by a primary failure, could result in personnel injury.

c. Such items identified by the analysis shall be designated safety critical and shall require the following considerations.

1. Specific Design Action

2. Special Safety Operating Requirements

3. Specific Hazard Identification and Proposed Corrective Action

4. Special Safety Supervision

d. Systems analysis data shall show that:

1. The system provides the capability of maintaining all pressure levels in a safe condition in the event of interruption of any process or control sequence at any time during test or countdown.

2. Redundant pressure relief devices have mutually independent pressure escape routes.

3. In systems where pressure regulator failure may involve critical hazard to the crew or mission success, regulation is redundant and where passive redundant systems are specified includes automatic switchover.

4. When the hazardous effects of safety critical failures or malfunctions are prevented through the use of redundant components or systems, it shall be mandatory that all such redundant components or systems are operational prior to the initiation of irreversible portions of safety critical operations or events.

3.12.1.5.3 Flight Hardware Pressure Vessel and Pressurized Structure Stress Analysis.

a. General Requirements. A detailed and comprehensive stress analysis of each pressure vessel and pressurized structure shall be conducted under the assumption of no crack-like flaws in the structure.

1. The analysis shall determine stresses resulting from the combined effects of internal pressure, ground or flight loads, and thermal gradients.

2. Both membrane stresses and bending stresses resulting from internal pressure and external loads shall be calculated to account for the effects of geometrical discontinuities, design configuration, and structural support attachments.

3. Loads shall be combined by using the appropriate design limit or ultimate safety factors on the individual loads and comparing the results to material allowables.

4. Safety factors shall be as determined in Section 3.12.2.

5. Safety factors on external (support) loads shall be as assigned to primary structure supporting the pressurized system.

b. Metallic Pressure Vessels and Pressurized Structures

1. For metallic pressure vessels and pressurized structures, classical solutions are acceptable if the design geometries and loading conditions are sufficiently simple and the results are sufficiently accurate to warrant their application.

2. Finite element or other equivalent structural analysis techniques shall be used to calculate the stresses, strains, and displacements for complex geometries and loading conditions.

3. Local structural models shall be constructed, as necessary, to augment the overall structural model in areas of rapidly varying stresses.

4. Minimum material gage as specified in the design drawings shall be used in calculating stresses.

5. The allowable material strengths shall reflect the effects of temperature, thermal cycling and gradients, processing variables, and time associated with the design environments.

6. Minimum margins of safety associated with the parent materials, weldments and heat-affected zones shall be calculated and tabulated for all pressure vessels and pressurized structures along with their locations and stress levels.

7. The margins of safety shall be positive against the strength and stiffness requirements of Sections 3.12.1.7 and 3.12.1.8, respectively.

c. Composite Hardware

1. For composite overwrapped pressure vessels (COPVs) and pressurized structures made of composite materials, the state-of-the-art methodology using composite laminate theory shall be employed.

2. Interlamination normal and shear stresses as well as in-plane stress components shall be calculated.

3. Effects of ply orientation, stacking sequence, and geometrical discontinuities shall be accounted for.

3.12.1.5.4 Flight Hardware Pressure Vessels and Pressurized Structure Fatigue Analysis. When conventional fatigue analysis is used to demonstrate the fatigue-life of an unflawed pressure vessel or pressurized structure, nominal values of fatigue-life characteristics including stress-life (S-N) data, strain-life (ε - N) data of the structural materials shall be used.

a. These data shall be taken from reliable sources such as MIL-HDBK-5, the *Aerospace Structural Metals Handbook* or other sources approved by the procuring agency.

b. The analysis shall account for the spectra of expected operating loads, pressure and environments.

c. Fatigue damage cumulative technique such as Miner's rule is an acceptable method for handling variable amplitude fatigue cyclic loadings.

3.12.1.5.5 Flight Hardware Pressure Vessel and Pressurized Structure Safe-Life Analysis. When crack growth safe-life analysis is used to demonstrate safe-life of a pressure vessel or a pressurized structure, undetected flaws shall be assumed to be in the critical locations and in the most unfavorable orientation with respect to the applied stress and material properties.

a. The size of the flaws shall be based on either the appropriate non-destructive inspection (NDI) techniques or defined by the acceptance proof testing.

b. Both the crack growth safe-life analysis and the proof test flaw screening logic, if utilized, shall be based on the state-of-the-art fracture mechanics methodology.

c. Nominal values of fracture toughness and fatigue crack-growth rate data associated with each alloy, temper, product form, thermal, and chemical environments shall be used in the safe-life analysis. However, if proof test logic is used for the determining of the initial flaw size, an upper bound fracture toughness value shall be used in determining both the initial flaw size and the critical flaw size at fracture.

d. Pressure vessels or pressurized structures that experience sustained stresses shall also show that the corresponding maximum stress intensity factor (K_{MAX}) during sustained load in operation is less than the stress-corrosion cracking threshold (K_{ISCC}) data in the appropriate environment, $K_{MAX} < K_{ISCC}$.

e. State-of-the-art crack growth software package shall be used to conduct the safe-life analysis.

f. Aspect ratio (a/2c) changes shall be accounted for in the analysis.

g. Retardation effects on crack growth rates from variable amplitude loading shall not be considered without approval by the procuring agency.

h. Tensile residual stresses shall be included in the analysis.

i. The safe-life analysis shall be included in the stress analysis report. In particular, loading spectra, environments, assumed initial flaw sizes, crack-growth models, fatigue crack growth rate and fracture data, shall be delineated. Summary of significant results shall be clearly presented.

3.12.1.6 Flight Hardware Pressure Vessel and Pressurized Structures Loads, Pressures, and Environments

a. The entire anticipated load-pressure-temperature history and associated environments throughout the service life shall be determined in accordance with specified mission requirements.

b. At a minimum, the following factors and their statistical variations shall be considered:

1. The environmentally induced loads and pressures.

2. The environments acting simultaneously with these loads and pressures with their proper relationships.

3. The frequency of application of these loads, pressures, environments, and their levels and duration.

c. These data shall be used to define the design load and environment spectra that shall be used for both design analysis and testing. The design spectra shall be revised as the structural design develops and the loads analysis matures.

3.12.1.7 Flight Hardware Pressure Vessel and Pressurized Structure Strength Requirements

a. All pressure vessels and pressurized structures shall possess sufficient strength to withstand limit loads and MEOP in the expected operating environments throughout their respective service lives without experiencing detrimental deformation.

b. They shall also withstand ultimate loads and design burst pressure in the expected operating environments without experiencing rupture or collapse.

c. Pressure vessels and pressurized structures shall be capable of withstanding ultimate external loads and ultimate external pressure (destab-ilizing) without collapse or rupture when internally pressurized to the minimum anticipated operating pressure.

d. All pressure vessels and pressurized structures shall sustain proof pressure without incurring gross yielding or detrimental deformation and shall sustain design burst pressure without rupture.

e. When proof tests are conducted at temperatures other than design temperatures, the change in material properties at the proof temperature shall be accounted for in determining proof pressure.

f. Pressurized structures subject to instability modes of failure shall not collapse under ultimate loads nor degrade the functioning of any system due to elastic buckling deformation under limit loads.

g. Evaluation of buckling strength shall consider the combined action of primary and secondary stresses and their effects on general instability, local or panel instability, and crippling.

h. Design loads for buckling shall be ultimate loads, except that any load component that tends to alleviate buckling shall not be increased by the ultimate design safety factor.

i. Destabilizing pressures shall be increased by the ultimate design factor, but internal stabilizing pressures shall not be increased unless they reduce structural capability.

j. The margin of safety shall be positive and shall be determined by analysis or test at design ultimate and design limit levels, when appropriate, at the temperatures expected for all critical conditions.

3.12.1.8 Flight Hardware Pressure Vessel and Pressurized Structure Stiffness Requirements

a. Pressure vessels and pressurized structures shall possess adequate stiffness to preclude detrimental deformation at limit loads and pressures in the expected operating environments throughout their respective service lives.

b. The stiffness properties of pressure vessels and pressurized structures shall be such as to prevent all detrimental instabilities of coupled vibration modes, minimize detrimental effects of the loads and dynamics response that are associated with structural flexibility, and avoid adverse contact with other vehicle systems.

3.12.1.9 Flight Hardware Pressure Vessel and Pressurized Structure Thermal Requirements

a. Thermal effects, including heating rates, temperatures, thermal gradient, thermal stresses and deformations, and changes in the physical and mechanical properties of the material of construction shall be considered in the design of all pressure vessels and pressurized structures.

b. These effects shall be based on temperature extremes that simulate those predicted for the operating environment plus a design margin as specified in MIL-STD-1540 or equivalent.

3.12.1.10 Composite Overwrapped Pressure Vessels Requirements

Additional design and test requirements for graphite epoxy (Gr/EP) composite overwrapped pressure vessels (COPVs) can be found in the 23 November 1993 letter "Interim Safety Requirements for Design, Test, and Ground Processing of Flight Graphite Epoxy (Gr/EP) Composite Overwrapped Pressure Vessels (COPVs) at the Kennedy Space Center (KSC), Cape Canaveral Air Force Station (CCAFS), and Vandenberg Air Force Base (VAFB)" issued by the Director, Safety and Reliability, NASA, KSC and the Chiefs of Safety, USAF, 30 SW and 45 SW. **NOTE 1:** The requirements stipulated in this letter are interim requirements for GR/EP COPVs. Final requirements will be incorporated in this document when the results of the GR/EP COPV test programs are complete. **NOTE:** A copy of the interim safety requirements may be obtained from the Safety Office.

3.12.1.11 Physical Arrangement of Flight Hardware Pressure Systems and System Components

3.12.1.11.1 General Requirements.

a. The design of hypergolic systems shall take into consideration limitations imposed on individuals dressed in SCAPE during fill and drain operations.

b. Sufficient clearances are needed for the insertion of assembly tools.

c. Redundant pressure components and systems shall be separated from main systems for maximum safety advantage in case of damage, fire, or malfunction.

d. Pressure systems shall be shielded from other systems when required to minimize all hazards caused by proximity to combustible gases, heat sources, and electrical equipment.

e. Any failure in any such adjacent system shall not result in combustion or explosion of pressure fluids or components.

f. Safety critical pressure systems shall be designed so that special tools shall not be required for removal and replacement of components unless it can be shown that the use of special tools is unavoidable.

3.12.1.11.2 Components and Fixtures.

a. Fixtures for safe handling and hoisting with coordinated attachment points in the system structure shall be provided for equipment that cannot be hand carried.

b. Components shall be designed so that, during the assembly of parts, sufficient clearance exists to permit assembly of the components without damage to seals, O-rings, or backup rings where they pass over threaded parts or sharp corners.

c. Pressure fluid reservoirs shall be shielded or isolated from combustion apparatus or other heat sources.

d. Handling and hoisting loads shall be in accordance with MIL-STD-8512 or equivalent.

e. All incompatible propellant system connections shall be keyed, sized, or located so that it is physically impossible to interconnect them.

3.12.1.11.3 Tubing and Piping.

a. In general, tubing and piping shall be located so that damage will not occur due to being stepped on, used as handholds, or by manipulation of tools during installation.

b. Straight tubing and piping runs shall be avoided between two rigid connection points.

c. Where such straight runs are necessary, provisions shall be made for expansion joints, motion of the units, or similar compensation to insure that no excessive strains will be applied to the tubing and fittings.

d. Line bends shall be used to ease stresses induced in tubing by alignment tolerances and vibration.

3.12.1.11.4 Valves, Vents, Vent Lines, and Drains.

a. Manually operated valves should be located to permit operation from the side or above to prevent spillage of service fluid on the operator due to leak or failure of the valve seals.

b. For remotely controlled valves, positive indication of actual valve position shall be displayed at the control station. **NOTE 1**: Indication of valve stem position or flow measurement is an acceptable indication. **NOTE 2**: Indication of an electrical control circuit actuation is not a positive indication of valve position.

c. Vent lines for flammable and combustible vapors shall be extended away from work areas to prevent accidental ignition of vapors and/or injury to personnel.

d. Vent outlets shall be located far enough away from incompatible propellant systems and incompatible materials to ensure no contact is made during vent operations.

e. Safety valves and burst diaphragms shall be located so that their operation will not cause injury to personnel standing close by or damage to the installation or equipment, or they shall be equipped with deflection devices to protect personnel and equipment.

f. Lines, drains, and vents shall be separated or shielded from other high-energy systems; for example, heat, high voltage, combustible gases, and chemicals.

g. Drain and vent lines shall not be connected to any other lines in any way that could generate a hazardous mixture in the drain/vent line, or allow feedback of hazardous substances to the components being drained or vented.

h. When lines are required for draining liquid explosive, flammable liquids or explosive waste, they shall be free of pockets or low spots so that a positive flow is achieved at all points in the drain line.

i. The slope shall not be less than 1/4 inch per foot at any point on the drain line.

j. The drain system shall include a sump or basin where the fluid can safely collect. This sump or basin shall be designed so that it can be easily cleaned, and drainage easily removed.

3.12.1.11.5 Test Points.

a. If required, test points shall be provided so that disassembly for test is not required.

b. The test points shall be easily accessible for attachment of ground test equipment.

c. Common-plug test connectors for pressure and return sections shall be designed to require positive removal of the pressure connection prior to unsealing the return connections.

d. Individual pressure and return test connectors shall be designed to positively prevent inadvertent cross-connections.

3.12.1.12 Flight Hardware Pressure System and Pressurized Structures Supports and Clamps

a. All rigid pipe and tubing assemblies shall be supported by a firm structure to restrain destructive vibration, shock, and acceleration.

b. Components within a system should be supported by a firm structure and not the connecting tubing or piping unless it can be shown by analysis that the tubing or piping can safely support the component.

c. Pipe and tube accessories such as supports, anchors, and braces shall be compatible with hypergolic vapors when installed in a hypergolic propellant system.

d. All threaded parts in safety critical components shall be securely locked to resist uncoupling forces by acceptable safe design methods.

e. Safety wiring and self-locking nuts are examples of acceptable safe design.

f. Torque for threaded parts in safety critical components shall be specified.

g. Friction-type locking devices shall be avoided in safety critical applications.

h. Star washers and jam nuts shall not be used as locking devices.

i. The design of internally threaded bosses shall preclude the possibility of damage to the component or the boss threads because of screwing universal fittings to excessive depths in the bosses.

j. Retainers or snap rings shall not be used in pressure systems where failure of the ring would allow connection failures or blow-outs caused by internal pressure.

k. Snubbers shall be used with all Bourdon-type pressure transmitters, pressure switches, and pressure gauges, except air pressure gauges.

3.12.1.13 Flight Hardware Pressure System Bonding and Grounding

a. Hazardous pressure systems shall be designed so that the flight system being loaded or unloaded and the ground support loading system can be commonly grounded and bonded during transfer operations. When the flight system and the ground system are connected, maximum DC resistance from any flight system tubing or tanks to the nearest earth electrode plate shall be 100 milliohms or less. **NOTE:** See paragraph 3.11.1.18.6.

b. Propellant system components and lines shall be grounded to metallic structures.

c. All hazardous pressure systems shall be properly bonded to the flight vehicle to minimize the DC resistance between the hazardous pressure system and the flight vehicle.

3.12.1.14 Flight Hardware Pressure System and Pressurized Structure Material Compatibility and Selection

3.12.1.14.1 Compatibility.

a. Materials shall be compatible throughout their intended service life with the service fluids and the materials used in the construction and installation of tankage, piping, and components as well as with nonmetallic items such as gaskets, seals, packing, seats, and lubricants.

b. At a minimum, material compatibility shall be determined in regard to flammability, ignition and combustion, toxicity, and corrosion.

c. Materials that could come in contact with fluid from a ruptured or leaky tank, pipe, or other components that contain hazardous fluids shall be nonflammable and non-combustible.

d. Compatible materials selection shall be obtained from one of the following sources:

1. T.O. 00-25-223

2. Chemical Propulsion Information Agency (CPIA) 394

3. MSFC-HDBK-527

4. Compatibility test criteria and test results shall be submitted to Range Safety for review and approval.

e. Compatibility Analysis. The Range User shall prepare a compatibility analysis containing the following information:

1. List of all materials used in system

2. Service fluid in contact with each material

3. Source document or test results showing material compatibility in regards to flammability, toxicity, corrosion, and ignition and combustion

3.12.1.14.2 Selection.

a. Material "A" allowable values shall be used for pressure vessels, and pressurized structures where failure of a single load path would result in loss of structural integrity.

b. For redundant pressurized structures where failure of a structural element would result in a safe redistribution of applied loads to other load-carrying members, material "B" allowables may be used.

c. The fracture toughness shall be as high as practicable within the context of structural efficiency and fracture resistance.

d. For pressure vessels and pressurized structures to be analyzed with linear elastic fracture mechanics, fracture properties shall be accounted for in material selection.

e. These properties include fracture toughness; threshold values of stress intensity under sustained loading; subcritical crack-growth characteristics under sustained and cyclic loadings; the effects of fabrication and joining processes; the effects of cleaning agents, dye penetrants, coatings and proof test fluids; and the effects of temperature, load spectra, and other environmental conditions.

f. Materials that have a low K_{ISCC}, in the expected operating environments shall not be used in pressure vessels and pressurized structures unless adequate protection from the operating environments can be demonstrated by tests.

g. If the material has a less than 60 percent of the plane-strain fracture toughness, K_{Ic}, under the conditions of its application, it shall be mandatory to show, by a “worst case” fracture mechanics analysis, that the low threshold stress intensity factor will not precipitate premature structural failure.

3.12.1.15 Flight Hardware Pressure System Contamination and Cleanliness Requirements

a. Adequate levels of contamination control shall be established by relating the cleanliness requirements to the actual needs and nature of the system and components.

b. General contamination control requirements are as follows:

1. Components and systems shall be protected from contaminants by adequate filtration, sealed modules, clean fluids, and clean environment during assembly, storage installation, and use.

2. Systems shall be designed to verify that the lines and components are clean after flushing and purging the system.

3. Systems shall be designed to ensure that contaminants or waste fluids can be flushed and purged after fill and drain operations.

3.12.1.16 Flight Hardware Pressure System Components Service Life and Safe Life

a. All hazardous pressure system components shall be designed for safe endurance against hazardous failure modes for not less than 400 percent of the total number of expected prelaunch cycles.

b. The safe-life shall be determined by analysis, test, or both, and shall be at least four times the specified service life for those pressure vessels and pressurized structures that are not accessible for periodic inspection and repair.

c. For those pressure vessels and pressurized structures that are readily accessible for periodic inspection and repair, the safe-life, as determined by analysis and test, shall be at least four times the interval between scheduled inspection and/or refurbishment.

d. All pressure vessels and pressurized structures that require periodic refurbishment to meet safe-life requirements shall be recertified after each refurbishment by the same techniques and procedures used in the initial certification, unless an alternative recertification plan has been approved by the procuring agency.

3.12.1.17 Flight Hardware Metallic Materials

3.12.1.17.1 Selection. Metallic materials shall be selected on the basis of proven environmental compatibility, material strengths, fracture properties, fatigue life, and crack growth characteristics consistent with the overall program requirements.

3.12.1.17.2 Evaluation. Metallic material evaluation shall be conducted based on the following considerations:

a. The metallic materials selected for design shall be evaluated with respect to material processing, fabrication methods, manufacturing operations, refurbishment procedures and processes, and other pertinent factors that affect the resulting strength and fracture properties of the material in the fabricated as well as the refurbished configurations.

b. The evaluation shall ascertain that the mechanical properties, strengths, and fracture properties used in design and analyses will be realized in the actual hardware and that these properties are compatible with the fluid contents and the expected operating environments.

c. Materials that are susceptible to stress-corrosion cracking or hydrogen embrittlement shall be evaluated by performing sustained thres-hold-stress-intensity tests when applicable data are not available.

3.12.1.17.3 Characterization. Metallic material characterization shall be based on the following considerations:

a. The allowable mechanical properties, strength and fracture properties of all metallic materials selected for pressure vessels and pressurized structures shall be characterized in sufficient detail to permit reliable and high confidence predictions of their structural performance in the expected operating environments unless these properties are available from reliable sources such as MIL-HDBK-5, ASTM Standards, *Damage Tolerant Design Handbook*, MIL Specifications, *Aerospace Structural Metals Handbook*, and other sources approved by the procuring agency.

b. Where material properties are not available, they shall be determined by test methods approved by the procuring agency.

c. The characterization shall produce the following strength and fracture properties for the parent metals, weldments, and heat-affected zones as a function of the fluid contents, loading spectra, and the expected operating environments, including proof test environments, as appropriate:

1. Tensile yield strength, σ_{ys}, and ultimate tensile strength, σ_u

2. Fracture toughness, K_{Ic}, K_{Ie}, K_c, K_{ISCC}

3. Sustained-stress crack-growth data, da/dt versus K_{max}

4. Fatigue crack-growth data, da/dn versus ΔK and load ratio, R

d. Proven test procedures shall be used for determining material fracture properties as required. **NOTE:** These procedures shall conform to recognized standards, such as standard test methods developed by the American Society for Testing and Materials (ASTM).

e. The test specimens and procedures used shall provide valid test data for the intended application.

f. Enough tests shall be conducted so that meaningful nominal values of fracture toughness and crack-growth rate data corresponding to each alloy system, temper, product form, thermal and chemical environments and loading spectra can be established to evaluate compliance with safe-life requirements.

g. If the conventional fatigue analysis is to be performed, the stress-life (S-N) or the strain-life (ε-N) fatigue data need to be generated in accordance with the standard test methods developed by ASTM.

3.12.1.17.4 Fabrication and Process Control. Proven processes and procedures for fabrication and repair shall be used to preclude damage or material degradation during material processing, manufacturing operations, and refurbishment.

a. In particular, special attention shall be given to ascertain that the melt process, thermal treatment, welding process, forming, joining, machining, drilling, grinding, repair and rewelding operations, etc., are within the state-of-the-art and have been used on similar hardware.

b. The fracture toughness, mechanical and physical properties of the parent materials, weldments and heat-affected zones shall be within established design limits after exposure to the intended fabrication processes.

c. The machining, forming, joining, welding, dimensional stability during thermal treatments, and through-thickness hardening characteristics of the material shall be compatible with the fabrication processes to be encountered.

d. Fracture control requirements and precautions shall be defined in applicable drawings and process specifications.

e. Detailed fabrication instructions and controls shall be provided to ensure proper implementation of the fracture control requirements.

f. Special precautions shall be exercised throughout the manufacturing operations to guard against processing damage or other structural degradation. In addition, procurement requirements and controls shall be implemented to ensure that suppliers and subcontractors employ fracture control procedures and precautions consistent with the fabrication and inspection processes intended for use during actual hardware fabrication.

3.12.1.18 Flight Hardware Pressure Vessel and Pressurized Structure Quality Assurance Program Requirements

a. A quality assurance (QA) program, based on a comprehensive study of the product and engineering requirements, such as drawings, material specifications, process specifications, workmanship standards, design review records, and failure mode analysis, shall be established to ensure that the necessary NDI and acceptance tests are effectively performed to verify that the product meets the requirements of this document.

b. The program shall ensure that materials, parts, subassemblies, assemblies, and all completed and refurbished hardware conform to applicable drawings and process specifications; that no damage or degradation has occurred during material processing, fabrication, inspection, acceptance tests, shipping, storage, operational use and refurbishment; and that defects that could cause failure are detected or evaluated and corrected.

3.12.1.18.1 QA Program Inspection Plan. At a minimum, the following considerations shall be included in structuring the quality assurance program:

a. An inspection master plan shall be established prior to start of fabrication.

b. The plan shall specify appropriate inspection points and inspection techniques for use throughout the program, beginning with material procurement and continuing through fabrication, assembly, acceptance proof test, operation, and refurbishment, as appropriate.

c. In establishing inspection points and inspection techniques, consideration shall be given to the material characteristics, fabrication processes, design concepts, structural configuration and accessibility for inspection of flaw.

d. For metallic hardware, the flaw geometries shall encompass defects commonly encountered, including surface crack at the open surface, corner crack or through-the-thickness crack at the edge of fastener hole, and surface crack at the root of intersecting prismatic structural elements.

e. Acceptance and rejection standards shall be established for each phase of inspection, and for each type of inspection technique.

f. For composite pressure vessels or COPVs, defects such as delamination, fiber breakage, surface cut or dent, shall be considered.

3.12.1.18.2 Inspection Techniques. At a minimum, the following considerations shall be included in determining the appropriate inspection techniques:

a. The selected NDI inspection techniques for metallic hardware must have the capability to determine the size, geometry, location and orientation of a flaw or defect; to obtain, where multiple flaws exist, the location of each with respect to the other and the distance between them; and to differentiate among defect shapes, from tight cracks to spherical voids.

b. Two or more NDI methods shall be used for a part or assembly that cannot be adequately examined by only one method.

c. The flaw detection capability of each selected NDI technique for metallic hardware or the metallic liner of a COPV shall be based on past experience on similar hardware.

d. Where this experience is not available or is not sufficiently extensive to provide reliable results, the capability, under production or operational inspection conditions, shall be determined experimentally and demonstrated by tests approved by the procuring agency on representative material product form, thickness, and design configuration.

e. The flaw detection capability shall be expressed in terms of detectable crack length and crack depth.

f. The selected NDI should be capable of detecting allowable initial flaw size corresponding to a 90 percent probability of detection at a 95 percent confidence level.

g. The most appropriate NDI technique(s) for detecting commonly encountered flaw types shall be used for all metallic pressure vessels, pressurized structures, and other hardware based on their flaw detection capabilities.

3.12.1.18.3 Inspection Data. At a minimum, inspection data shall be dispositioned as follows:

a. Inspection data in the form of flaw histories shall be maintained throughout the life of the pressure vessel and pressurized structure.

b. These data shall be periodically reviewed and assessed to evaluate trends and anomalies associated with the inspection procedures, equipment and personnel, material characteristics, fab-rication processes, design concept and structural configuration.

c. The result of this assessment shall form the basis of any required corrective action.

3.12.1.18.4 Flight Hardware Pressure Vessels, Pressurized Structures, and Pressurized System Components Acceptance Proof Test.

a. All pressure vessels, pressurized structures, and pressure components shall be proof-pressure tested in accordance with the requirements of Sections 3.12.2 through 3.12.5, as applicable, to verify that the hardware has sufficient structural integrity to sustain the subsequent service loads, pressure, temperatures, and environments.

b. For pressure vessels, pressurized structures, and other pressurized components, the temperature shall be consistent with the critical use temperature, or, as an alternative, tests may be conducted at an alternate temperature if the test pressures are suitably adjusted to account for temperature effects on strength and fracture toughness.

c. Proof-test fluids shall be compatible with the structural materials in the pressure vessels and pressurized structures.

d. Proof test fluids shall not pose a hazard to test personnel.

e. If such compatibility data is not available, required testing shall be conducted to demonstrate that the proposed test fluid does not deteriorate the test article.

f. Accept/reject criteria shall be formulated prior to the acceptance proof test.

g. Every pressure vessel and pressurized structure shall not leak, rupture, or experience gross yielding during acceptance testing.

3.12.1.19 Flight Hardware Pressure Systems and Pressurized Structures Operations and Maintenance

3.12.1.19.1 Safe Operating Limits.

a. Safe operating limits shall be established for each pressure vessel and each pressurized structure based on the appropriate analysis and testing employed in its design and qualification in accordance with Sections 3.12.2, 3.12.3, and 3.12.4.

b. These safe operating limits shall be summarized in a format that will provide rapid visibility of the important structural characteristics and capability.

3.12.1.19.2 Operating Procedures.

a. Operating procedures shall be established for each pressure vessel and pressurized structure.

b. These procedures shall be compatible with the safety requirements and personnel control requirements at the facility where the operations are conducted.

c. Step-by-step directions shall be written with sufficient detail to allow a qualified technician or mechanic to accomplish the operations.

d. Schematics that identify the location and pressure limits of relief valves and burst discs shall be provided when applicable, and procedures to insure compatibility of the pressurizing system with the structural capability of the pressurized hardware shall be established.

e. Prior to initiating or performing a procedure involving hazardous operations with pressure systems, practice runs shall be conducted on non-pressurized systems until the operating procedures are well rehearsed.

f. Initial tests shall then be conducted at pressure levels not to exceed 50 percent of the normal operating pressures until operating characteristics can be established and stabilized.

g. Only qualified and trained personnel shall be assigned to work on or with high pressure systems.

h. Warning signs with the hazard(s) identified shall be posted at the operations facility prior to pressurization.

3.12.1.19.3 Inspection and Maintenance.

a. The results of the appropriate stress, and safe-life analyses shall be used in conjunction with the appropriate results from the structural development and qualification tests to develop a quantitative approach to inspection and repair.

b. Allowable damage limits shall be established for each pressure vessel and pressurized structure so that the required inspection interval and repair schedule can be established to maintain hardware to the requirements of this document.

c. NDI technique(s) and inspection procedures to reliably detect defects and determine flaw size under the condition of use shall be developed for use in the field and depot levels.

d. Procedures shall be established for recording, tracking, and analyzing operational data as it is accumulated to identify critical areas requiring corrective actions.

e. Analyses shall include prediction of remaining life and reassessment of required inspection intervals.

3.12.1.19.4 Repair and Refurbishment.

a. When inspections reveal structural damage or defects exceeding the permissible levels, the damaged hardware shall be repaired, refurbished, or replaced, as appropriate.

b. All repaired or refurbished hardware shall be recertified after each repair and refurbishment by the applicable acceptance test procedure for new hardware to verify their structural integrity and to establish their suitability for continued service.

3.12.1.19.5 Storage Requirements.

a. When pressure vessels and pressurized structures are put into storage, they shall be protected against exposure to adverse environments that could cause corrosion or other forms of material degradation.

b. They shall be protected against mechanical degradation resulting from scratches, dents, or accidental dropping of the hardware.

c. Induced stresses due to storage fixture constraints shall be minimized by suitable storage fixture design.

d. In the event storage requirements are violated, recertification shall be required prior to acceptance for use.

3.12.1.19.6 Reactivation.

a. Pressure vessels and pressurized structures that are reactivated for use after an extensive period in either an unknown, unprotected, or unregulated storage environment shall be recertified to ascertain their structural integrity and suitability for continued service before commitment to flight.

b. Recertification tests for pressurized hardware shall be in accordance with the appropriate Recertification Test Requirement.

3.12.1.20 Flight Hardware Pressure Systems and Pressurized Structures Documentation Requirements

a. Inspection, maintenance, and operation records shall be kept and maintained throughout the life of each pressure vessel and each pressurized structure.

b. At a minimum, the records shall contain the following information:

1. Temperature, pressurization history, and pressurizing fluid for both tests and operations

2. Number of pressurizations experienced as well as number allowed in safe-life analysis

3. Results of any inspection conducted, including: inspector, inspection dates, inspection techniques employed, location and character of defects, defect origin, and cause

4. Storage condition

5. Maintenance and corrective actions performed from manufacturing to operational use, including refurbishment

6. Sketches and photographs to show areas of structural damage and extent of repairs

7. Acceptance and recertification test performed, including test conditions and results

8. Analyses supporting the repair or modification that may influence future use capability

3.12.2 Flight Hardware Pressure Vessels Design, Analysis, and Test Requirements

3.12.2.1 Flight Hardware Metallic Pressure Vessels General Design, Analysis, and Verification Requirements

Two approaches for the design, analysis and verification of metallic pressure vessels can be selected as shown in Figure 3-1. Selection of the approach to be used depends on the desired efficiency of design coupled with the level of analysis and verification testing required.

3.12.2.1.1 Approach A. Approach A in Figure 3-1 shows the steps required for verification of a metallic pressure vessel designed with a burst factor equal to 1.5 or greater.

a. Based on the results of the failure mode determination, one of two distinct verification paths must be satisfied: (1) leak-before-burst (LBB) with leakage of the contents not creating a condition that could lead to a mishap (such as Toxic gas venting or pressurization of a compartment not capable of the pressure increase, and (2) brittle failure mode or LBB in which, if allowed to leak, the leak causes a hazard.

b. The verification requirements for path 1 are delineated in Section 3.12.2.2, and the verification requirements for path 2 in Section 3.12.2.3.

3.12.2.1.2 Approach B. Approach B, Figure 3-1 shows the steps required for verification of a metallic pressure vessel designed using the ASME Boiler and Pressure Vessel Code or the Department of Transportation Pressure Vessel Codes.

3.12.2.2 Flight Hardware Metallic Pressure Vessels with Non-Hazardous LBB Failure Mode

a. The LBB failure mode shall be demonstrated analytically or by test showing that an initial surface flaw with a shape (a/2c) ranging from 0.05 to 0.5 will propagate through the vessel thickness to become a through-the-thickness crack with a length less than or equal to ten times the vessel thickness and will still be stable at MEOP.

b. Fracture mechanics shall be used if the failure mode is determined by analysis.

c. A pressure vessel that contains non-hazardous fluid and exhibit LBB failure mode is considered as a non-hazardous LBB pressure vessel.

3.12.2.2.1 Factor of Safety Requirements.

a. Metallic pressure vessels that satisfy the non-hazardous LBB failure mode criterion may be designed conventionally, wherein the design factors of safety and proof test factors are selected on the basis of successful past experience.

b. Unless otherwise specified, the minimum burst factor shall be 1.5.

3.12.2.2.2 Fatigue-Life Demonstration.

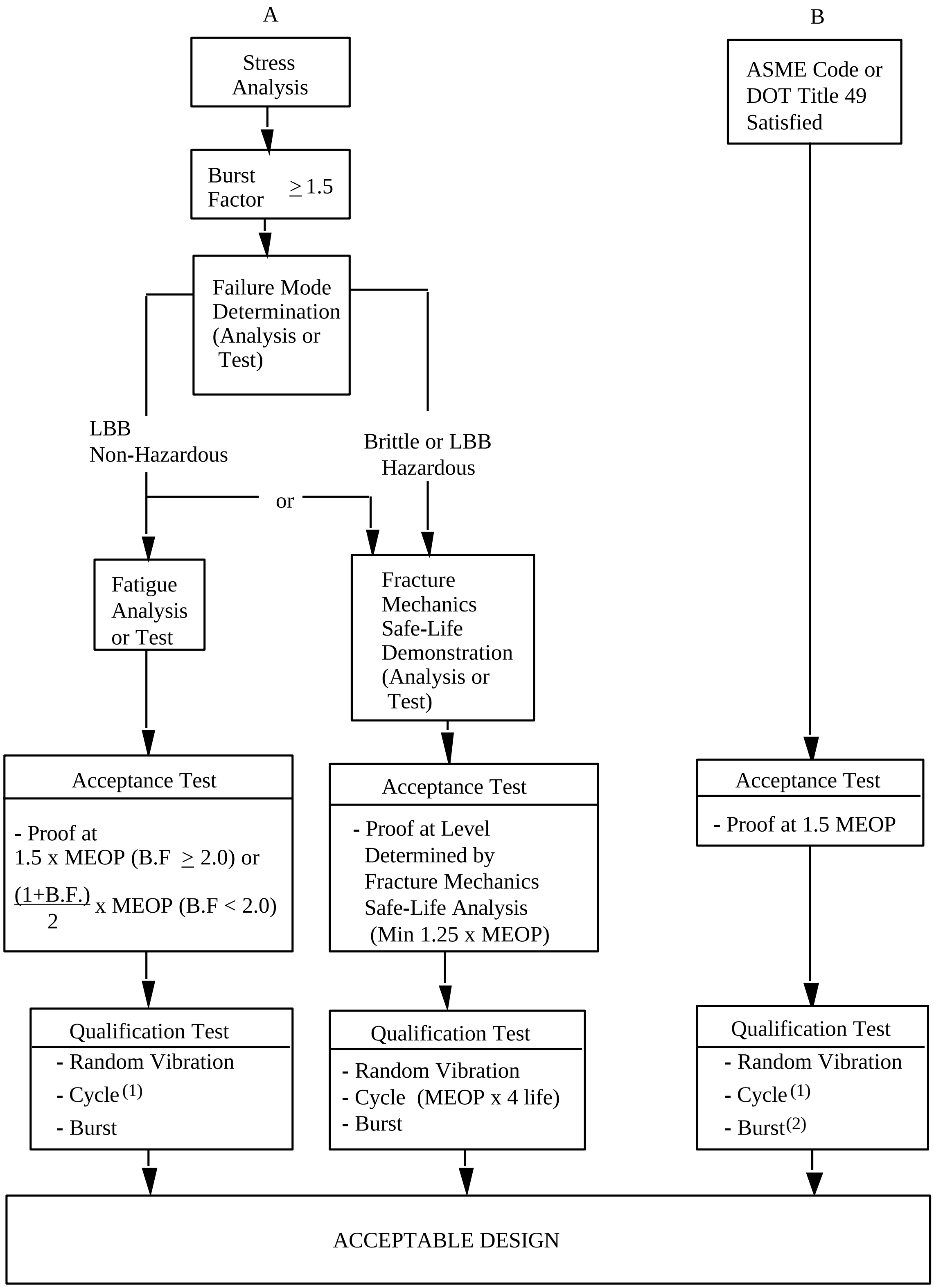
a. After completion of the stress analysis conducted in accordance with the requirements of Section 3.12.2.5, conventional fatigue-life analysis shall be performed, as appropriate, on the unflawed structure to ascertain that the pressure vessel, acted upon by the spectra of operating loads, pressures, and environments will meet the life requirements.

b. A life factor of 5 shall be used in the analysis.

c. Testing of unflawed specimens to demonstrate fatigue-life of a specific pressure vessel together with stress analysis is an acceptable alternative to fatigue test of the vessel.

d. Fatigue-life requirements are considered demonstrated when the unflawed specimens that represent critical areas such as membrane section, weld joints, heat-affected zone, and boss transition section successfully sustain the limit loads and MEOP in the expected operating environments for the specified test duration without rupture.

e. The required test duration is four times the specified service life.



NOTES: (1) Cycle test at either MEOP x 4-life or 1.5 MEOP x 2 life
(2) Burst or disposition vessel with approval of the procuring agency

Figure 3-1. Pressure Vessel Design Verification Approach

3.12.2.2.3 Qualification Test Requirements.

a. Qualification tests shall be conducted on flight-quality hardware to demonstrate structural adequacy of the design.

b. The test fixtures, support structures, and methods of environmental application shall not induce erroneous test conditions.

c. The types of instrumentation and their locations in qualification tests shall be based on the results of the stress analysis of Section 3.12.1.5.3.

d. The instrumentation shall provide sufficient data to ensure proper application of the accept/-reject criteria, which shall be established prior to test.

e. The sequences, combinations, levels, and duration of loads, pressure, and environments shall demonstrate that design requirements have been met.

f. Qualification testing shall include random vibration testing and pressure testing. The following delineates the required tests:

1. Random Vibration Testing. Random vibration qualification testing shall be performed in accordance with the requirements of MIL-STD-1540 or equivalent unless it can be shown that the vibration requirement is enveloped by other qualification testing performed.

2. Pressure Testing. Required qualification pressure testing levels are shown in Table 3-1. Requirement for application of external loads in combination with internal pressures during testing must be evaluated based on the relative magnitude and/or destabilizing effect of stresses due to the external load. If limit combined tensile stresses are enveloped by test pressure stresses, the application of external loads shall not be required. If the application of external loads is required, the load shall be cycled to limit for four times the predicted number of operating cycles of the most severe design condition (e.g., destabilizing load with constant minimum internal pressure or maximum additive load with a constant maximum expected operating pressure.

3.12.2.2.4 Acceptance Test Requirements.

a. Acceptance tests shall be conducted on every pressure vessel before commitment to flight. Accept/reject criteria shall be formulated prior to tests.

b. The test fixtures and support structures shall be designed to permit application of all test loads without jeopardizing the flightworthiness of the test article.

c. At a minimum, the following are required:

1. Non-Destructive Inspection. A complete inspection by the selected non-destructive inspection (NDI) technique(s) shall be performed prior to proof pressure test to establish the initial condition of the hardware.

2. Proof Pressure Test. Every pressure vessel shall be proof-pressure tested to verify that the materials, manufacturing processes, and workmanship meet design specifications and that the hardware is suitable for flight. The proof pressure shall be equal to:

$$P_{proof} = \left(\frac{1 + \text{Burst Factor}}{2} \right) \times \left(\text{MEOP} \right)$$

for burst factor less than 2.0 or 1.5 x (MEOP) for burst factor equal or greater than 2.0

3.12.2.2.5 Recertification Test Requirements. All refurbished pressure vessels shall be recertified

Table 3-1
Qualification Pressure Test Requirements

Test Item	No Yield after	No Burst at(1)
Vessel #1(2)		Burst Factor x MEOP
Vessel #2	Cycle at 1.5 x MEOP for 2x predicted number of service life. (50 cycles minimum) or Cycle at 1.0 x MEOP for 4x predicted number of service life. (50 cycles minimum)	Burst Factor x MEOP

(1) Unless otherwise specified, after demonstrating no burst at the design burst pressure test level, increase pressure to actual burst of vessel. Record actual burst pressure.
(2) Test may be deleted at discretion of the Range User.

after each refurbishment by the acceptance test requirements for new hardware to verify their structural integrity and to establish their suitability for continued service before commitment to flight. Pressure vessels that have exceeded the approved storage environment (temperature, humidity, time, and others) shall also be recertified by the acceptance test requirements for new hardware.

3.12.2.2.6 Special Provisions. For one-of-a-kind applications, a proof test of each flight unit to a minimum of 1.5 times MEOP and a conventional fatigue analysis showing a minimum of 10 design lifetimes may be used in lieu of the required pressure testing as defined in paragraph 3.12.2.1.f.6 (b). The implementation of this option needs prior approval by the procuring agency and the appropriate launch and/or test range approval authority.

3.12.2.3 Flight Hardware Metallic Pressure Vessels with Brittle Fracture or Hazardous LBB Failure Mode.

3.12.2.3.1 Factor of Safety Requirements.

a. Safe-life design methodology based on fracture mechanics techniques shall be used to establish the appropriate design factor of safety and the associated proof factor for metallic pressure vessels that exhibit brittle fracture or hazardous leak-before-burst failure mode.

b. The loading spectra, material strengths, fracture toughness, and flaw-growth rates of the parent material and weldments, test program requirements, stress levels, and the compatibility of the structural materials with the thermal and chemical environments expected in service shall be taken into consideration.

c. Nominal values of fracture toughness and flaw-growth rate data corresponding to each alloy system, temper, and product form shall be used along with a life factor of four on specified service life in establishing the design factor of safety and the associated proof factor.

d. Unless otherwise specified the minimum burst factor shall be 1.5.

3.12.2.3.2 Safe-Life Demonstration Requirements.

a. After completion of the stress analysis conducted in accordance with the requirements of Section 3.12.1.5.3, safe-life analysis of each pressure vessel covering the maximum expected operating loads and environments, shall be performed under the assumption of pre-existing initial flaws or cracks in the vessel.

b. In particular, the analysis shall show that the metallic pressure vessel with flaws placed in the most unfavorable orientation with respect to the applied stress and material properties, of sizes defined by the acceptance proof test or NDI and acted upon by the spectra of expected operating loads and environments, will meet the safe-life requirements of 3.12.1.16.

c. Nominal values of fracture toughness and flaw-growth rate data associated with each alloy system, temper, product form, thermal and chemical environments, and loading spectra shall be used along with a life factor of four on specified service life in all safe-life analyses.

d. Pressure vessels that experience sustained stress shall also show that the corresponding applied stress intensity (K_I) during operation is less than K_{ISCC} in the appropriate environment.

e. Testing of metallic pressure vessels under fracture control in lieu of safe-life analysis is an acceptable alternative, provided that, in addition to following a quality assurance program (Section 4.6) for each flight article, a qualification test program is implemented on pre-flawed specimens representative of the structure design.

f. These flaws shall not be less than the flaw sizes established by the acceptance proof test or the selected NDI method(s).

g. Safe-life requirements of 3.12.1.16 are considered demonstrated when the pre-flawed test specimens successfully sustain the limit loads and pressure cycles in the expected operating environments without rupture.

h. A life factor of four on specified service life shall be applied in the safe-life demonstration testing.

i. A report that documents the fracture mechanics safe-life analysis or safe-life testing shall be prepared to delineate the following:

1. Fracture mechanics data (fracture toughness and fatigue crack growth rates)
2. Loading spectrum and environments
3. Initial flaw sizes
4. Analysis assumptions and rationales
5. Calculation methodology
6. Summary of significant results
7. References

j. This report shall be closely coordinated with the stress analysis report and shall be periodically revised and updated during the life of the program.

3.12.2.3.3 Qualification Test Requirements.

a. Qualification tests shall be conducted on flight-quality hardware to demonstrate structural adequacy of the design.

b. The test fixtures, support structures, and methods of environmental application shall not include erroneous test conditions.

c. The types of instrumentation and their locations in qualification tests shall be based on the results of the stress analysis of Section 3.12.1.5.3.

d. The instrumentation shall provide sufficient data to ensure proper application of the accept/reject criteria, which shall be established prior to test.

e. The sequences, combinations, levels, and duration of loads, pressure and environments shall demonstrate that design requirements have been met.

f. Qualification testing shall include random vibration testing, and pressure testing. The following delineates the required tests:

1. Random Vibration. Random vibration qualification testing shall be performed per requirements of MIL-STD-1540 or equivalent unless it can be shown the vibration requirement is enveloped by other qualification testing performed.

2. Pressure Testing. Required qualification pressure testing levels are shown in Table 3-1. Requirement for application of external loads in combination with internal pressures during testing must be evaluated based on the relative magnitude and/or destabilizing effect of stresses due to the external load. If limit combined tensile stresses are enveloped by test pressure stresses, the application of external loads shall not be required. If the application of external loads is required, the load shall be cycled to limit for four times the predicted number of operating cycles of the most severe design condition (e.g., destabilizing load with constant minimum internal pressure, or maximum additive load with constant maximum expected operating pressure). Qualification test procedure shall be approved by the procuring agency and the appropriate launch or test range approval authority.

3.12.2.3.4 Acceptance Test Requirements. The acceptance test requirements for pressure vessels that exhibit brittle fracture, or hazardous LBB, failure mode are identical to those with ductile fracture failure mode as defined in Section 3.12.2.2.4 except that test level shall be that defined by the fracture mechanics analysis whenever possible. Surface and Volume NDI shall be performed before and after proof test on the weld joints as a minimum. Cryo-proof acceptance test procedures may be required to adequately verify initial flaw size. The pressure vessel shall not rupture or leak at the acceptance test pressure.

3.12.2.3.5 Recertification Test Requirements. All refurbished pressure vessels shall be recertified after each refurbishment by the acceptance test requirements for new hardware to verify their structural integrity and to establish their suitability for continued service before commitment to flight. Pressure vessels that have exceeded the approved storage environment (temperature, humidity, time, etc.) shall also be recertified by the acceptance test requirements for new hardware.

3.12.2.3.6 Special Provisions. For one-of-a-kind applications, a proof test of each flight unit to a minimum of 1.5 times MEOP and a conventional fatigue analysis showing a minimum of 10 design lifetimes may be used in lieu of the required pressure testing as defined in Section 3.12.2.2.3 for qualification. The implementation of this option needs prior approval by Range Safety.

3.12.2.4 Flight Hardware Metallic Pressure Vessels Designed Using ASME Boiler Code

Metallic pressure vessels may be designed and manufactured per the rules of the ASME Boiler and Pressure Vessel Code, Section VIII, Divisions 1 or 2.

3.12.2.4.1 Qualification Test Requirements.

a. Required qualification pressure testing levels are shown in Table 3-1.

b. Requirement for application of external loads in combination with internal pressures during testing must be evaluated based on the relative magnitude and/or destabilizing effect of stresses due to the external load.

c. If limit combined tensile stresses are enveloped by test pressure stresses, the application of external loads shall not be required.

d. If the application of external loads is required, the load shall be cycled to limit for four times the predicted number of operating cycles of the most severe design condition (for example, destabilizing load with constant minimum internal pressure, or maximum additive load with constant MEOP).

3.12.2.4.2 Acceptance Test Requirements.

a. A proof test shall be performed as specified in ASME Code pressure test at 1.5 x MAWP unless otherwise prohibited by the Code.

b. NDI shall be performed in accordance with the ASME Code and RT and/or UT as appropriate to quantify defects in all full penetration welds after the proof test.

3.12.2.5 Flight Hardware Metal-Lined Composite Overwrapped Pressure Vessels

Flight Hardware composite overwrapped pressure vessels (COPVs) with metallic liners may be designed using either of the two paths of Approach A shown in Figure 3-1. The failure mode designation for a metal lined COPV shall be based on its environment and operational criteria while used at the launch site. Additional guidance can be found in paragraph 3.12.1.10.

3.12.2.6 COPVs with Non-Hazardous LBB Failure Mode

a. Applicable fracture mechanics analysis and/-or tests of metal lined composite pressure vessels shall verify the LBB failure mode of the metal liner.

b. In particular the effects of the liner sizing operation on the fracture mechanics characteristics of the liner should be accounted for in the LBB evaluation.

3.12.2.6.1 Factor of Safety Requirements.

a. Nonmetallic pressure vessels that satisfy the non-hazardous LBB failure mode criterion may be designed conventionally, wherein the design factors of safety and proof test factors are selected on the basis of successful past experience.

b. Unless otherwise specified, the minimum burst factor shall be 1.5.

3.12.2.6.2 Fatigue-Life Demonstration.

a. After completion of the stress analysis conducted in accordance with the requirements of Section 3.12.1.5.3, conventional fatigue-life analy-sis shall be performed, as appropriate, on the unflawed structure to ascertain that the pressure vessel, acted upon by the spectra of operating loads, pressures and environments will meet the life requirements.

b. A life factor of 5 shall be used in the analysis.

3.12.2.6.3 Qualification Test Requirements.

a. Qualification tests shall be conducted on flight-quality hardware to demonstrate structural adequacy of the design.

b. The test fixtures, support structures, and methods of environmental application shall not induce erroneous test conditions.

c. The types of instrumentation and their locations in qualification tests shall be based on the results of the stress analysis of Section 3.12.1.5.3.

d. The instrumentation shall provide sufficient data to ensure proper application of the accept/reject criteria, that shall be established prior to test.

e. The sequences, combinations, levels, and duration of loads, pressures, and environments shall demonstrate that design requirements have been met.

f. Qualification testing shall include random vibration testing and pressure testing. The following delineates the required tests:

1. Random Vibration Testing. Random vibration qualification testing shall be performed in accordance with the requirements of MIL-STD-1540 or equivalent unless it can be shown that the vibration requirement is enveloped by other qualification testing performed.

2. Pressure Testing

(a) Required qualification pressure testing levels are shown in Table 3-1.

(b) Requirement for application of external loads in combination with internal pressures during testing shall be evaluated based on the relative magnitude and/or destabilizing effect of stresses due to the external load.

(c) If limit combined tensile stresses are enveloped by test pressure stresses, the application of external loads shall not be required.

(d) If the application of external loads is required, the load shall be cycled to limit four times the predicted number of operating cycles of the most severe design condition (for example, destabilizing load with constant minimum internal pressure or maximum additive load with a constant MEOP).

3.12.2.6.4 Acceptance Test Requirements.

a. Acceptance tests shall be conducted on every pressurized structure before commitment to flight.

b. Accept/reject criteria shall be formulated prior to tests.

c. The test fixtures and support structures shall be designed to permit application of all test loads without jeopardizing the flightworthiness of the test article.

d. At a minimum, the following are required:

1. A complete inspection by the selected nondestructive inspection (NDI) technique(s) shall be performed prior to proof pressure test to establish the initial condition of the hardware.

2. Every pressurized structure shall be proof tested to verify that the materials, manufacturing processes, and workmanship meet design specifications and that the hardware is suitable for flight. Unless otherwise specified, the proof pressure shall be 1.1 times MEOP.

3.12.2.6.5 Recertification Test Requirements.

a. All refurbished pressure vessels shall be recertified after each refurbishment by the acceptance test requirements for new hardware to verify their structural integrity and to establish their suitability for continued service before commitment to flight.

b. Pressure vessels that have exceeded the approved storage environment (temperature, humidity, time, and others) shall also be recertified by the acceptance test requirements for new hardware.

3.12.2.7 Flight Hardware COPVs with Brittle Fracture or Hazardous LBB Failure Mode

This section is applicable only to flight hardware COPVs with metal liners that exhibit brittle fracture or hazardous LBB failure mode.

3.12.2.7.1 Factor of Safety Requirements. Unless otherwise specified the minimum burst factor shall be 1.5.

3.12.2.7.2 Safe-Life Demonstration Requirements.

a. In addition to the stress analysis conducted in accordance with the requirements of Section 3.12.1.5.3, safe-life analysis of each pressure vessel covering the maximum expected operating loads and environments, shall be performed under the assumption of pre-existing initial flaws or cracks in the vessel.

b. In particular, the analysis shall show that the metallic pressure vessel with flaws placed in the most unfavorable orientation with respect to the applied stress and material properties, of sizes defined by the acceptance proof test or NDI and acted upon by the spectra of expected operating loads and environments, will meet the safe-life requirements of Section 3.12.1.16.

c. Nominal values of fracture toughness and flaw-growth rate data associated with each alloy system, temper, product form, thermal and chemical environments, and loading spectra shall be used along with a life factor of four on specified service life in all safe-life analyses.

d. Pressure vessels that experience sustained stress shall also show that the corresponding applied stress intensity (K_I) during operation is less than K_{ISCC} in the appropriate environment.

e. Testing of metallic pressure vessels under fracture control in lieu of safe-life analysis is an acceptable alternative, provided that, in addition to following a quality assurance program for each flight article, a qualification test program is implemented on pre-flawed specimens representative of the structure design.

f. These flaws shall not be less than the flaw sizes established by the acceptance proof test or the selected NDI method(s).

g. Safe-life requirements of Section 3.12.1.16 are considered demonstrated when the pre-flawed test specimens successfully sustain the limit loads and pressure cycles in the expected operating environments without rupture.

h. A life factor of four on specified service life shall be applied in the safe-life demonstration testing.

i. A report that documents the fracture mechanics safe-life analysis or safe-life testing shall be prepared to delineate the following:

1. Fracture mechanics data (fracture toughness and fatigue crack growth rates)

2. Loading spectrum and environments

3. Initial flaw sizes

4. Analysis assumptions and rationales

5. Calculation methodology

6. Summary of significant results

7. References

j. This report shall be closely coordinated with the stress analysis report and shall be periodically revised and updated during the life of the program.

3.12.2.7.3 Fatigue Life Demonstration. For fatigue life demonstration requirements, see section 3.12.2.6.2.

3.12.2.7.4 Qualification Test Requirements.

a. Qualification tests shall be conducted on flight-quality hardware to demonstrate structural adequacy of the design.

b. The test fixtures, support structures, and methods of environmental application shall not include erroneous test conditions.

c. The types of instrumentation and their locations in qualification tests shall be based on the results of the stress analysis of Section 3.12.1.5.3.

d. The instrumentation shall provide sufficient data to ensure proper application of the accept/-reject criteria, which shall be established prior to test.

e. The sequences, combinations, levels, and duration of loads, pressure and environments shall demonstrate that design requirements have been met.

f. Qualification testing shall include random vibration testing, and pressure testing. The following delineates the required tests:

1. Random Vibration. Random vibration qualification testing shall be performed per requirements of MIL-STD-1540 unless it can be shown the vibration requirement is enveloped by other qualification testing performed.

2. Pressure Testing. Required qualification pressure testing levels are shown in Table 3-1. Requirement for application of external loads in combination with internal pressures during testing must be evaluated based on the relative magnitude and/or destabilizing effect of stresses due to the external load. If limit combined tensile stresses are enveloped by test pressure stresses, the application of external loads shall not be required. If the application of external loads is required, the load shall be cycled to limit for four times the predicted number of operating cycles of the most severe design condition such as destabilizing load with constant minimum internal pressure, or maximum additive load with constant maximum expected operating pressure.

3.12.2.7.5 Acceptance Test Requirements.

a. Acceptance tests shall be conducted on every pressure vessel before commitment to flight. Accept/reject criteria shall be formulated prior to tests.

b. The test fixtures and support structures shall be designed to permit application of all test loads without jeopardizing the flightworthiness of the test article.

c. The following are required as a minimum.

1. Non-Destructive Inspection. A complete volumetric and surface inspection by the selected non-destructive inspection (NDI) technique(s) shall be performed prior to proof pressure test to establish the initial condition of the hardware.

2. Proof Pressure Test. Every COPV shall be proof-pressure tested to verify that the materials, manufacturing processes, and workmanship meet design specifications and that the hardware is suitable for ground processing safety. At a minimum, the proof pressure duration time shall meet or exceed a 30 minute hold time at proof pressure. The proof pressure shall be equal to:

$$P_{\text{proof}} = \left(\frac{1 + \text{Burst Factor}}{2}\right) \times (\text{MEOP})$$

or 1.5 x (MEOP) for burst factor equal or greater than 2.0

3.12.2.7.6 Recertification Test Requirements. All refurbished pressure vessels shall be recertified after each refurbishment by the acceptance test requirements for new hardware to verify their structural integrity and to establish their suitability for continued service before commitment to flight. Pressure vessels that have exceeded the approved storage environment (temperature, humidity, time, and others) shall also be recertified by the acceptance test requirements for new hardware.

3.12.2.8 Flight Hardware Composite Pressure Vessels

Composite pressure vessels shall be designed and manufactured per the rules of the ASME Boiler and Pressure Code, Section X.

3.12.2.8.1 Qualification Test Requirements. Qualification testing shall include random vibration testing, and pressure testing. The following delineates the required tests:

a. Random Vibration. Random vibration qualification testing shall be performed per requirements of MIL-STD-1540 unless it can be shown the vibration requirement is enveloped by other qualification testing performed.

b. Pressure Testing. Required qualification pressure testing levels are shown in Table 3-1. Requirement for application of external loads in combination with internal pressures during testing must be evaluated based on the relative magnitude and/or destabilizing effect of stresses due to the external load. If limit combined tensile stresses are enveloped by test pressure stresses, the application of external loads shall not be required. If the application of external loads is required, the load shall be cycled to limit for four times the predicted number of operating cycles of the most severe design condition such as destabilizing load with constant minimum internal pressure, or maximum additive load with constant maximum expected operating pressure.

3.12.2.8.2 Acceptance Test Requirements. Composite pressure vessels shall be proof pressure tested at 1.5 x MEOP, unless prohibited by Code.

3.12.3 Flight Hardware Metallic Pressurized Structures Analysis and Test Requirements

3.12.3.1 Flight Hardware Metallic Pressurized Structures General Requirements

For pressurized structures made of metallic materials such as the fuel tanks of a launch or an upper-stage vehicle, the design approach may be based on successful past experience when appropriate. However, the analysis and verification requirements specified in this section shall be met.

3.12.3.2 Flight Hardware Metallic Pressurized Structures with Non-Hazardous LBB Failure Mode

3.12.3.2.1 Factor of Safety Requirements. Unless otherwise specified, metallic pressurized structures that satisfy the LBB failure mode may be designed with a minimum ultimate safety factor of 1.25 for unmanned systems and 1.40 for manned systems.

3.12.3.2.2 Fatigue-Life Demonstration. In addition to the stress analysis conducted in accordance with the requirements of Section 3.12.1.5.3, conventional fatigue-life analysis shall be performed, as appropriate, on the unflawed structure to ascertain that the pressure vessel, acted upon by the spectra of operating loads, pressures and environments will meet the life requirements. A life factor of five shall be used in the analysis.

3.12.3.2.3 Qualification Test Requirements.

a. Qualification tests shall be conducted on flight-quality hardware to demonstrate structural adequacy of the design.

b. Because of the potential test facility size limitation, the qualification testing may be conducted at the component level, provided that the boundary conditions are correctly simulated.

c. The test fixtures, support structures, and methods of environmental application shall not induce erroneous test conditions.

d. The sequences, combinations, levels, and duration of loads, pressure and environments shall demonstrate that design requirements have been met.

e. Qualification testing shall include pressure cycle testing and burst testing. The following delineates the required tests:

1. Pressure Cycle Testing

(a) Requirements for application of external loads in combination with internal pressure during testing shall be evaluated based on the relative magnitude and on the destabilizing effect of stresses due to the external loads.

(b) If limit combined tensile stresses are enveloped by the MEOP stress, the application of external load is not required.

(c) Unless otherwise specified, the peak pressure shall be equal to the MEOP during each pressure cycle, and the number of cycles shall be 4 times the predicted number of operating cycles or 50 MEOP cycles, whichever is greater.

(d) If the application of external loads is required, the load shall be cycled four (4) times the predicted number of operating cycles of the most severe design condition (e.g., destabilizing load with constant minimum internal pressure or maximum additive load with MEOP).

2. Burst Testing.

(a) After the pressure cycle testing, the test article shall be pressurized (pneumatically or hydrostatically, as applicable and safe) to the design burst pressure, while simultaneously applying the ultimate external loads, if appropriate.

(b) The design burst pressure shall be maintained for a period of time sufficiently to ensure that the proper pressure is achieved.

3.12.3.2.4 Acceptance Test Requirements.

a. Every pressurized structure shall be proof tested to verify that the materials, manufacturing processes, and workmanship meet design specifications and that the hardware is suitable for flight.

b. Acceptance tests shall be conducted on every pressurized structure before commitment to flight.

c. Accept/reject criteria shall be formulated prior to tests.

d. The test fixtures and support structures shall be designed to permit application of all test loads without jeopardizing the flightworthiness of the test article.

e. The following are required as a minimum:

1. A complete inspection by the selected surface and volumetric NDI techniques shall be performed prior to proof pressure test.

2. If personnel are exposed to the structure when pressurized above 50 percent of MEOP the minimum proof factor shall be 1.25. If personnel are not exposed to the structure when pressurized, the proof pressure factor shall be 1.1 times MEOP.

3. Every pressurized structure shall be proof-pressure tested to verify that the materials, manufacturing processes, and workmanship meet design specifications and that the hardware is suitable for ground processing safety. At a minimum, the proof pressure duration time shall meet or exceed a 5 minute hold time at proof pressure. The proof pressure shall be equal to:

$$P_{\text{proof}} = \left(\frac{1 + \text{Burst Factor}}{2}\right) \times (\text{MEOP})$$

or 1.5 x (MEOP) for burst factor equal or greater than 2.0

3.12.3.2.5 Recertification Test Requirements.

a. All refurbished pressure vessels shall be recertified after each refurbishment by the acceptance test requirements for new hardware to verify their structural integrity and to establish their suitability for continued service before commitment to flight.

b. Pressure vessels that have exceeded the approved storage environment (temperature, humidity, time, and others) shall also be recertified by the acceptance test requirements for new hardware.

3.12.3.3 Flight Hardware Metallic Pressurized Structures with Hazardous LBB or Brittle Failure Mode

3.12.3.3.1 Factor of Safety Requirements. Unless otherwise specified, metallic pressurized structures that satisfy the LBB failure mode may be designed with a minimum ultimate safety factor of 1.25 for unmanned systems and 1.40 for manned systems.

3.12.3.3.2 Safe-Life Demonstration.

a. Safe-life analysis of each pressurized structure shall be performed under the assumption of pre-existing initial flaws or cracks in the structure as specified in Section 3.12.1.5.5.

b. In particular, the analysis shall show that the pressurized structure with flaws, placed in the most unfavorable orientation with respect to the applied stress and material properties, of sizes defined by the acceptance proof test or NDI and acted upon by the spectra of expected operating loads, pressure and environments, will meet the safe-life requirements of Section 3.12.1.16.

c. Nominal values of fracture toughness and flaw-growth rate data associated with each alloy system, temper, product form, thermal and chemical environments, and loading spectra shall be used along with a life factor of four on specified service life in all safe-life analysis.

d. Safe-life testing in lieu of safe-life analysis is an acceptable alternative, provided that, in addition to following a quality assurance program for each flight article, a qualification test program is implemented on pre-flawed specimens representative of the structural design.

e. These flaws shall not be less than the flaw sizes established by the acceptance proof test or the selected NDI method(s).

f. Safe-life requirements of Section 3.12.1.16 are considered demonstrated when the pre-flawed test specimens successfully sustain the limit loads and pressure cycles in the expected operating environments.

g. A life factor of four on specified pressure cycles in the service life shall be applied in the safe-life demonstration testing.

3.12.3.3.3 Qualification Test Requirements. Qualification testing shall include pressure cycle testing and burst testing. The following delineates the required tests:

a. Pressure Cycle Testing

1. Requirements for application of external loads in combination with internal pressure during testing shall be evaluated based on the relative magnitude and on the destabilizing effect of stresses due to the external loads.

2. If limit combined tensile stresses are enveloped by the MEOP stress, the application of external load is not required.

3. Unless otherwise specified, the peak pressure shall be equal to the MEOP during each pressure cycle, and the number of cycles shall be 4 times the predicted number of operating cycles or 50 MEOP cycles, whichever is greater.

4. If the application of external loads is required, the load shall be cycled 4 times the predicted number of operating cycles of the most severe design condition; for example, destabilizing load with constant minimum internal pressure or maximum additive load with MEOP.

b. Burst Testing

1. After the pressure cycle testing, the test article shall be pressurized (pneumatically or hydrostatically, as applicable and safe) to the design burst pressure, while simultaneously applying the ultimate external loads, if appropriate.

2. The design burst pressure shall be maintained for a period of time sufficiently to ensure that the proper pressure is achieved.

3. Unless otherwise specified, the minimum design burst pressure shall be 1.25 times MEOP for unmanned systems, and 1.4 times for manned systems.

3.12.3.3.4 Acceptance Test Requirements.

a. The acceptance test requirements for pressurized structures that exhibit brittle fracture failure mode or hazardous LBB failure mode are identical to those with non-hazardous LBB failure mode as defined in Section 3.12.3.2 except that the selected NDI techniques shall be capable of detecting flaws or cracks smaller than the allowable initial flaw size as determined by safe-life analysis.

b. Surface and volumetric NDI shall also be performed on welds before and after proof testing if personnel are exposed to the structure when pressurized above 50 percent of MEOP. If personnel will not be exposed to pressures greater than 50 percent perform surface and volumetric NDI on welds after proof test.

3.12.3.3.5 Recertification Test Requirements.

a. All refurbished pressure vessels shall be recertified after each refurbishment by the acceptance test requirements for new hardware to verify their structural integrity and to establish their suitability for continued service before commitment to flight.

b. Pressure vessels that have exceeded the approved storage environment (temperature, humidity, time, and others) shall also be recertified by the acceptance test requirements for new hardware.

3.12.4 Flight Hardware Special Pressurized Equipment Design, Analysis, and Test Requirements

Batteries, cryostats (or dewars), heat pipes, and sealed containers are classified as special pressurized equipment. This section presents the detailed requirements design, analysis, and test requirements for this equipment.

3.12.4.1 Batteries with LBB Failure Mode

The battery cells shall be demonstrated to have a LBB failure mode per Section 3.12.2.2; and when sealed battery cases are used, they shall also be demonstrated to have a LBB failure mode.

3.12.4.1.1 Factor of Safety. Unless otherwise specified, the minimum burst factors for battery cells and sealed battery cases shall be 1.5.

3.12.4.1.2 Fatigue-Life Demonstration.

a. In addition to the stress analysis conducted in accordance with the requirements of Section 3.12.1.5.3, conventional fatigue-life analysis shall be performed, as appropriate, on the unflawed structure to ascertain that the pressure vessel, acted upon by the spectra of operating loads, pressures and environments will meet the life requirements.

b. A life factor of 5 shall be used in the analysis.

c. Testing of unflawed specimens to demonstrate fatigue-life of a specific pressure vessel together with stress analysis is an acceptable alternative to fatigue test of the vessel.

d. Fatigue-life requirements are considered demonstrated when the unflawed specimens that represent critical areas such as membrane section, weld joints, heat-affected zone, and boss transition section successfully sustain the limit loads and MEOP in the expected operating environments for the specified test duration without rupture.

e. The required test duration is four times the specified service life.

3.12.4.1.3 Qualification Testing.

a. Qualification tests shall be conducted on flight quality batteries to demonstrate structural adequacy of the design.

b. The following tests are required:

1. Random Vibration Testing. Random vibration testing shall be performed on batteries per requirements of MIL-STD-1540.

2. Thermal Vacuum Testing. Thermal vacuum test shall be performed on batteries per requirements of MIL-STD-1540.

3. Pressure Testing. A pressure cycle test shall be conducted on battery cells. The peak pressure shall be equal to the MEOP of the battery cells during each cycle, and the number of cycles shall be 4 times the predicted number of operating cycles or 50 cycles, whichever is greater. After the completion of the pressure cycle test, the pressure shall be increased to actual burst of the battery cell. The actual burst pressure shall be greater than or equal to 1.5 times MEOP of the battery cell. For batteries having sealed cases, similar tests shall be conducted on the sealed cases, if applicable.

3.12.4.1.4 Acceptance Test Requirements.

a. Acceptance tests shall be conducted on batteries before being committed to flight.

b. The following tests are required:

1. Proof Pressure Test. Battery cells, whenever feasible, shall be proof-pressure tested to 1.25 times the MEOP of the cells. For sealed battery cases, pressure tests shall be performed at a level of 1.25 times the MEOP of the cases.

2. Non-destructive Inspection. Surface and volumetric NDI technique(s) shall be performed after the proof pressure test.

3.12.4.1.5 Recertification Test Requirements.

a. All refurbished pressure vessels shall be recertified after each refurbishment by the acceptance test requirements for new hardware to verify their structural integrity and to establish their suitability for continued service before commitment to flight.

b. Pressure vessels that have exceeded the approved storage environment (temperature, humidity, time, and others) shall also be recertified by the acceptance test requirements for new hardware.

3.12.4.1.6 Special Requirements. Batteries shall be designed such that battery cells are within containment devices (or cases). These containment devices (or cases) shall be demonstrated to be able to prevent the escape of any hazardous contents over an insignificant quantity deemed acceptable by the procuring and safety agencies.

3.12.4.2 Batteries with Brittle Fracture Failure Mode

a. Batteries with battery cells exhibiting brittle fracture failure mode shall meet the requirements defined in Section 3.12.3.3.

b. In addition, a thermal vacuum test shall be conducted as part of the qualification testing.

3.12.4.3 Cryostats or Dewars with LBB Failure Mode

3.12.4.3.1 General Requirements. Pressure containers of the cryostat or Dewar shall be demonstrated to exhibit LBB failure mode in accordance with the following criteria:

a. The LBB failure mode shall be demonstrated analytically or by test showing that an initial surface flaw with a shape (a/2c) ranging from 0.05 to 0.5 will propagate through the vessel thickness to become a through-the-thickness crack with a length 10 times the vessel thickness and will still remain stable, at MEOP.

b. Fracture mechanics shall be used if the failure mode is determined by analysis.

c. A pressure vessel that contains non-hazardous fluid and exhibit LBB failure mode is considered as a non-hazardous LBB pressure vessel.

3.12.4.3.2 Factor of Safety Requirements. Unless otherwise specified, the minimum burst factor for the pressure container of a cryostat shall be 1.5.

3.12.4.3.3 Qualification Testing. Qualification tests shall be conducted on flight quality hardware to demonstrate structural adequacy of the design. The following tests are required:

a. Random Vibration Testing. Random vibration testing shall be performed on cryostats per requirements of MIL-STD-1540.

b. Pressure Testing. The cryostat (dewar) shall be pressurized to the design burst pressure that is 1.5 times MEOP of the pressure container. The design burst pressure shall be maintained for a period of time sufficient to ensure that the proper pressure was achieved.

3.12.4.3.4 Acceptance Test Requirements.

a. Acceptance tests should be conducted on every cryostat (or dewar) before being committed to flight.

b. The following tests are required:

1. Proof-Pressure Test. Cryostats shall be proof-pressure tested to 1.25 times the MEOP of the pressure container.

2. Non-destructive Inspection. Surface and volumetric Selected NDI technique(s) shall be performed after proof pressure test.

3.12.4.3.5 Recertification Test Requirements. All refurbished pressure vessels shall be recertified after each refurbishment by the acceptance test requirements for new hardware to verify their structural integrity and to establish their suitability for continued service before commitment to flight. Pressure vessels that have exceeded the approved storage environment (temperature, humidity, time, and others) shall also be recertified by the acceptance test requirements for new hardware.

3.12.4.3.6 Special Requirements. Outer shells (vacuum jackets) shall have pressure relief capability to preclude rupture in the event of pressure container leakage. If pressure containers do not vent external to the cryostats (or dewars) but instead vent into the volume contained by outer shells, the relief devices of outer shells must be capable of venting at a rate to release full flow without outer shells rupturing. Relief devices must be redundant and individually capable of full flow. Furthermore, pressure relief devices must be certified to operate at the required condition of use.

3.12.4.4 Cryostats or Dewars with Brittle Fracture Failure Mode

3.12.4.4.1 Factor of Safety Requirements.

a. Safe-life design methodology based on fracture mechanics techniques shall be used to establish the appropriate design factor of safety and the associated proof factor for metallic pressure vessels that exhibit brittle fracture or hazardous leak-before-burst failure mode.

b. The loading spectra, material strengths, fracture toughness, and flaw-growth rates of the parent material and weldments, test program requirements, stress levels, and the compatibility of the structural materials with the thermal and chemical environments expected in service shall be taken into consideration.

c. Nominal values of fracture toughness and flaw-growth rate data corresponding to each alloy system, temper, and product form shall be used along with a life factor of four on specified service life in establishing the design factor of safety and the associated proof factor.

d. Unless otherwise specified the minimum burst factor shall be 1.5.

3.12.4.4.2 Safe-Life Demonstration Requirements.

a. After completion of the stress analysis conducted in accordance with the requirements of Section 3.12.1.16, safe-life analysis of each pressure container covering the maximum expected operating loads and environments, shall be performed under the assumption of pre-existing initial flaws or cracks in the vessel.

b. In particular, the analysis shall show that the metallic cryostat with flaws placed in the most unfavorable orientation with respect to the applied stress and material properties, of sizes defined by the acceptance proof test or NDI and acted upon by the spectra of expected operating loads and environments, will meet the safe-life requirements of Section 3.12.1.16.

c. Nominal values of fracture toughness and flaw-growth rate data associated with each alloy system, temper, product form, thermal and chemical environments, and loading spectra shall be used along with a life factor of four on specified service life in all safe-life analyses.

d. Cryostats that experience sustained stress shall also show that the corresponding applied stress intensity (K_I) during operation is less than K_{ISCC} in the appropriate environment.

e. Testing of metallic cryostats under fracture control in lieu of safe-life analysis is an acceptable alternative, provided that, in addition to following a quality assurance program (Section 3.12.1.18) for each flight article, a qualification test program is implemented on pre-flawed specimens representative of the structure design.

f. These flaws shall not be less than the flaw sizes established by the acceptance proof test or the selected NDI method(s).

g. Safe-life requirements of Section 3.12.1.16 are considered demonstrated when the pre-flawed test specimens successfully sustain the limit loads and pressure cycles in the expected operating environments without rupture.

h. A life factor of four on specified service life shall be applied in the safe-life demonstration testing.

i. A report that documents the fracture mechanics safe-life analysis or safe-life testing shall be prepared to delineate the following:

1. Fracture mechanics data (fracture toughness and fatigue crack growth rates)

2. Loading spectrum and environments

3. Initial flaw sizes

4. Analysis assumptions and rationales

5. Calculation methodology

6. Summary of significant results

7. References

j. This report shall be closely coordinated with the stress analysis report and shall be periodically revised and updated during the life of the program.

3.12.4.4.3 Qualification Test Requirements.

a. Qualification tests shall be conducted on flight-quality hardware to demonstrate structural adequacy of the design.

b. The test fixtures, support structures, and methods of environmental application shall not include erroneous test conditions.

c. The types of instrumentation and their locations in qualification tests shall be based on the results of the stress analysis of Section 3.12.1.5.3.

d. The instrumentation shall provide sufficient data to ensure proper application of the accept/reject criteria, which shall be established prior to test.

e. The sequences, combinations, levels, and duration of loads, pressure and environments shall demonstrate that design requirements have been met.

f. Qualification testing shall include random vibration testing, and pressure testing. The following delineates the required tests:

1. Random Vibration. Random vibration qualification testing shall be performed per requirements of MIL-STD-1540 or equivalent unless it can be shown the vibration requirement is enveloped by other qualification testing performed.

2. Pressure Testing. Required qualification pressure testing levels are shown in Table 3-1. Requirement for application of external loads in combination with internal pressures during testing must be evaluated based on the relative magnitude and/or destabilizing effect of stresses due to the external load. If limit combined tensile stresses are enveloped by test pressure stresses, the application of external loads shall not be required. If the application of external loads is required, the load shall be cycled to limit for four times the predicted number of operating cycles of the most severe design condition; for example, destabilizing load with constant minimum internal pressure, or maximum additive load with constant maximum expected operating pressure. The qualification test procedure shall be approved by the procuring agency and the appropriate launch or test range approval authority.

3.12.4.4.4 Acceptance Test Requirements.

a. The acceptance test requirements for cryostats that exhibit brittle fracture or hazardous LBB, failure mode are identical to those with ductile fracture failure mode as defined in Section 3.12.2.2.4 except that test level shall be that defined by the fracture mechanics analysis whenever possible.

b. At a minimum, surface and volumetric NDI techniques shall be performed on all weld joints before and after the proof test.

c. Cryo-proof acceptance test procedures may be required to adequately verify initial flaw size.

d. The pressure container shall not rupture or leak at the acceptance test pressure.

3.12.4.4.5 Recertification Test Requirements.

a. All refurbished cryostats shall be recertified after each refurbishment by the acceptance test requirements for new hardware to verify their structural integrity and to establish their suitability for continued service before commitment to flight.

b. Cryostats that have exceeded the approved storage environment (temperature, humidity, time, and others) shall also be recertified by the acceptance test requirements for new hardware.

3.12.4.4.6 Special Provisions.

a. For one-of-a-kind applications, a proof test of each flight unit to a minimum of 1.5 times MEOP and a conventional fatigue analysis showing a minimum of 10 design lifetimes may be used in lieu of the required pressure testing as defined in Section 3.12.2.4 for qualification.

b. The implementation of this option needs prior approval by the procuring agency and the appropriate launch and/or test range approval authority.

3.12.4.5 Flight Hardware Heat Pipe Requirements

3.12.4.5.1 Factor of Safety.

a. Unless otherwise specified, the minimum burst factors for heat pipes with a diameter greater than 1.5 in. shall be 2.5.

b. For heat pipes with a diameter less than or equal to 1.5 in., the minimum burst factor shall be 4.0.

3.12.4.5.2 Qualification Test Requirements. Pressure testing shall be conducted to demonstrate no failure at the design burst pressure.

3.12.4.5.3 Acceptance Test Requirements.

a. All fusion joints or full penetration welds on the heat pipes that contain hazardous fluids shall be inspected using an acceptable surface and volumetric NDI technique.

b. A proof pressure test shall be conducted to a minimum level of 1.5 times MEOP on all heat pipes.

3.12.4.5.4 Recertification Test Requirements.

a. All refurbished heat pipes shall be recertified after each refurbishment by the acceptance test requirements for new hardware to verify their structural integrity and to establish their suitability for continued service before commitment to flight.

b. Heat pipes that have exceeded the approved storage environment (temperature, humidity, time, and other environments) shall also be recertified by the acceptance test requirements for new hardware.

3.12.4.5.5 Special Requirements. The heat pipe material shall satisfy the material compatibility requirements defined in Section 3.12.1.17.2 for the contained fluid at both the proof test temperature and operational temperature.

3.12.4.6 Flight Hardware Sealed Containers

3.12.4.6.1 Sealed Containers with Non-Hazardous LBB Failure Mode. The LBB failure mode shall be demonstrated as defined in Section 3.12.2.2. *EXCEPTION: Those containers made of aluminum, stainless steel, or titanium sheets that are acceptable as LBB designs do not have to demonstrate LBB failure mode*.

a. Factor of Safety. Unless otherwise specified, the minimum burst factor shall be 1.5.

b. Qualification Test Requirements

1. Sealed containers containing non-elec-tronic equipment shall only be subjected to pressure testing.

2. For sealed containers containing electronic equipment, other qualification tests including functional, thermal vacuum, thermal cycling, random vibration, and pyro shock shall be conducted per MIL-STD-1540 or equivalent.

c. Acceptance Test Requirements. Sealed containers shall be proof pressure tested to a minimum level of 1.25 times maximum design pressure differential or MAWP.

d. Recertification Test Requirements

1. All refurbished sealed containers shall be recertified after each refurbishment by the acceptance test requirements for new hardware to verify their structural integrity and to establish their suitability for continued service before commitment to flight.

2. Sealed containers that have exceeded the approved storage environment (temperature, humidity, time, and others) shall also be recertified by the acceptance test requirements for new hardware.

3.12.4.6.2 Sealed Containers with Brittle Fracture or Hazardous LBB Failure Mode.

a. Sealed containers that exhibit a brittle fracture failure mode or contain hazardous fluid, or both, shall meet the requirements of Section 3.12.2.3.

b. For sealed containers containing electronic equipment, qualification tests including functional, thermal vacuum, thermal cycling, and pyro shock shall be conducted in addition to random vibration and pressure testing.

3.12.5 Flight Hardware Pressure System Component Design and Test Requirements

This section describes the requirements for the design and testing of flight hardware pressure system components. Included are hydraulic, pneu-matic, hypergolic, and cryogenic system components.

3.12.5.1 Flight Hardware Pneumatic and Hydraulic Pressure System Components

3.12.5.1.1 Factor of Safety Requirements. Flight hardware pneumatic and hydraulic pressure system components shall be designed to the minimum factor shown in Table 3-2.

Table 3-2
Pressure Components Safety Factors

	Proof	Design Burst
Lines and fittings dia < 1.5 in.	1.5	4.0
dia ≥ 1.5 in.	1.5	2.5
Fluid Return Sections	1.5	3.0
Fluid Return Hose	1.5	5.0
Other pressure Components	1.5	2.5

Components subject to low or negative pressures shall be evaluated at 2.5 times maximum external pressure expected during service life.

3.12.5.1.2 Flight Hardware Pneumatic and Hydraulic Pressure System Component General Selection and Design Requirements.

a. Components shall be selected to ensure that misconnections or reverse installations within the subsystem are not possible. **NOTE:** Color codes, labels, and directional arrows shall be used to identify hazards and direction of flow.

b. The maximum fluid temperature shall be estimated early in design as part of data for selection of safety critical components, such as system fluid, pressurizing gas, oil coolers, and gaskets.

c. Components that are capable of safe actuation under pressure equal to the maximum relief valve setting in the circuit in which they are installed shall be specified.

d. Pumps, valves and regulators, hoses, and all such prefabricated components of a pressure system shall have proven pressure service ratings equal to or higher than the limit-load (maximum expected operating pressure) and rated life of the system.

e. The Standards of the Hydraulic Institute shall be used in evaluating safety in pump selection.

f. Where leakage or fracture is hazardous to personnel or critical equipment, valves shall be selected so that failure occurs at the outlet threads of valves before the inlet threads or body of the valve fails under pressure.

g. Pressure regulators shall be selected to operate in the center 50 percent of their total pressure range and avoid creep and inaccuracies at either end of the full operating range.

h. In all cases, flareless tube fittings shall be properly present prior to pressure application.

i. Where system leakage can expose hydraulic fluid to potential ignition sources or is adjacent to a potential fire zone and the possibility of flame propagation exists, fire resistant or flame proof hydraulic fluid shall be used.

3.12.5.1.3 Oxygen System Components.

a. Valves and other components shall be selected for oxygen systems of 3,000 psi or higher that are slow opening and closing types to minimize the potential for ignition of contaminants.

b. Such systems shall also require electrical grounding to eliminate the possibility of the build-up of static electrical charges.

3.12.5.1.4 Manual Valves and Regulators.

a. Manually operated valves and regulators shall be selected so that overtorquing of the valve stem or regulator adjustment cannot damage soft seats to the extent that failure of the seat will result.

b. Valve designs that use uncontained seats are unacceptable and shall not be selected.

3.12.5.1.5 Warning Devices and Safety Critical Components.

a. Warning devices that are activated by hazardous over or under pressure shall be selected whenever necessary.

b. The device shall either activate automaticresponse mechanisms or shall notify operational personnel of impending hazards.

c. Warning devices to indicate hazardous over or under pressures to operating personnel shall be specified.

d. These devices shall actuate at predetermined pressure levels designed to allow time for corrective action.

e. Safety critical actuation of pneumatic systems shall not be adversely affected by any back pressure resulting from concurrent operations of any other parts of the system under any set of conditions.

f. Components that can be isolated and contain residual pressure shall be equipped with gage reading and bleed valves for pressure safety check.

g. Bleed valves shall be directed away from operating personnel.

h. Fittings or caps for bleeding pressure are not acceptable.

i. Pressurized reservoirs that are designed for gas/fluid separation with provisions to entrap gas that may be hazardous to the system or safety critical actuation and prevent its recirculation in the system shall be specified. This shall include the posting of instructions adjacent to the filling point for proper bleeding when servicing.

j. Compressed gas emergency systems shall be bled directly to the atmosphere away from the vicinity of personnel, rather than to reservoir.

k. If the gas is combustible, consideration shall be given to the selection of safety critical components and methods for reducing the potential for accidental ignition or explosion.

l. Where necessary to prevent a hazardous sequence of operations and provide a fail-safe capability at all times, interlocks shall be specified. For example, the OPEN position of remotely controlled valves that can hazardously pressurize lines leading to remotely controlled (or automatic) disconnect couplings shall be interlocked to preclude the OPEN valve position coincident with the disconnected condition of the couplings.

m. Pressure systems that combine several safety critical functions shall have sufficient controls for isolating failed functions, for the purpose of safety operating the remaining functions.

n. All pressure systems shall have pressure indicating devices to monitor critical flows and pressures marked to show safe upper and lower limits of system pressure.

o. The pressure indicators shall be located to be readily visible to the operating crew.

p. All systems shall be protected for pressure above 500 psi in all areas where damage can occur during servicing or other operational hazards.

q. Pressure lines and components of 500 psi or higher that are adjacent to safety critical equipment shall be shielded to protect such equipment in the event of leakage or burst of the pressure system.

r. Automatic disengagement of by-pass shall be provided for pneumatic systems that provide for manual takeover in the event of a hazardous situation.

s. Positive indication of disengagement shall be provided.

t. Safety Critical pneumatic actuators shall have positive mechanical stops at the extremes of safe motion.

u. Adjustable orifice restrictor valves shall not be used in safety critical pneumatic systems.

3.12.5.1.6 Pneumatic Components.

a. Pneumatic components (other than tanks) for safety critical systems shall exhibit safe endurance against hazardous failure modes for not less than 400 percent of the total number of expected cycles including system test.

b. The configuration of pneumatic components shall permit bleeding of entrapped moisture, lubricants, particulate material, or other foreign matter hazardous to this system.

c. Compressors that are designed to sustain not less than 2.5 x delivery pressure after allowance for loss of strength of the materials equivalent to not less than that caused by 1,000 hours aging at 275☜F shall be selected.

3.12.5.1.7 Design Loads.

a. Installation of all lines and components to withstand all expected acceleration and shock loads shall be specified.

b. Shock isolation mounts may be used if necessary to eliminate destructive vibration and interference collisions.

c. The mounting of components, including valves, on structures having sufficient strength to withstand torque and dynamic loads and not supported by the tubing shall be specified.

d. Light-weight components that do not require adjustment after installation (for example, check valves), may be supported by the tubing, provided that a tube clamp is installed on each such tube near the component.

e. Tubing shall be supported by cushioned steel tube clamps or by multiple-block type clamps that are suitably spaced to restrain destructive vibration.

3.12.5.1.8 Electrical/Electronic Devices.

a. Electrical components for use in potentially ignitable atmospheres shall be demonstrated to be incapable of causing an explosion in the intended application.

b. Electrically energized hydraulic components shall not propagate radio-frequency energy that is hazardous to other subsystems in the total system, or interfere in the operation of safety critical electronic equipment (Reference MIL-STD-464).

c. Grounding. Pressure system components and lines shall be electrically grounded to metallic structures.

d. All solenoids shall be capable of safely withstanding a test voltage of not less than 1500 V rms at 60 cps for 1 min between terminals and case at the maximum operating temperature of the solenoid in the functional envelope.

e. Electric Motor Driven Pumps. Electric motor driven pumps used in safety critical systems shall not be used for ground test purposes unless the motor is rated for reliable continuous and safe operation. Otherwise, the test parameters may perturb reliability calculations.

3.12.5.1.9 Pressure Relief Devices.

a. Pressure relief devices shall be specified on all systems having a pressure source that can exceed the maximum allowable pressure of the system, or where the malfunction/failure of any component can cause the maximum allowable pressure to be exceeded.

b. Relief devices are required downstream of all regulating valves and orifice restrictors unless the downstream system is designed to accept full source pressure.

c. On space systems, where operational or weight limitations preclude the use of relief valves, and systems will operate in an environment not hazardous to personnel, they can be omitted if the ground or support system contains such devices and they cannot be isolated from the airborne system during the pressurization cycle and the space vehicle cannot provide its own protection.

d. Where a ground system is specifically designed to service an unmanned flight vehicle, pressure relief protection may be provided within the ground equipment, if no capability exists to isolate the pressure relief protection from the flight vehicle during the pressurization cycle.

e. Where safety factors of less than 2.0 are used in the design of flight hardware pressure vessels, provide a means for automatic relief, depressurization, and pressure verification of a safety critical vessels in the event of launch abort.

f. Whenever any pressure volume can be confined and/or isolated by system valving, provide an automatic pressure relief device.

g. Pop-values, rupture discs, blow-out plugs, armoring, and construction to contain the greatest possible overpressure that may develop are examples of corrective measures for system safety in cases not covered by the above paragraphs.

h. Pressure relief devices shall be vented for toxic or inert gases to safe areas or scrubbers, away from the vicinity of personnel.

i. Shut-off valves for maintenance purposes on the inlet side of pressurized relief valves are permissible if a means for monitoring and bleeding trapped pressure is provided and the requirements of ASME Code for unfired pressure vessels, Appendix M, paragraph UA-354. It is mandatory that the valve be locked open when the system is repressurized.

j. Hydrostatic testing systems for vessels that are not designed to sustain negative internal pressure shall be equipped with fail-safe devices for relief of hazardous negative pressure during the period of fluid removal. Check valves and valve interlocks are examples of devices that can be used for this purpose.

k. Vessels that can be collapsed by a negative pressure shall have negative pressure relief and/or prevention devices for safety during storage and transportation.

l. Pressurized reservoirs shall be designed so that all ullage volumes are connected to a relief valve that shall protect the reservoir and power pump from hazardous overpressure or back pressure of the system.

m. The air pressure control for pressurized reservoirs shall be an externally nonadjustable pressure regulating device. If this unit also contains a reservoir pressure relief valve, it shall be designed so that no failure in the unit will permit overpressurization of the reservoir.

3.12.5.1.10 System Contamination Related Considerations.

a. The following contamination related considerations shall be addressed in the design of pressurized systems. NOTE: Contamination includes solid, liquid, and gaseous material.

1. Contamination shall be prevented from entering or developing within the system.

2. The system shall be designed to include provisions to detect contamination.

3. The system shall be designed to include provisions for removal of contamination and provisions for initial purge with fluid or gas that will not degrade future system performance.

4. The system shall be designed to be tolerant of contamination.

b. All pressurizing fluids entering safety critical system shall be filtered through a 10 micron filter, or finer, before entering the system.

c. All pressure systems shall have fluid filters in the system, designed and located to reduce the flow of contaminant particles to a safe minimum.

d. All of the circulating fluid in the system shall be filtered downstream from the pressure pump, or immediately upstream from safety critical actuators.

e. Entrance of contamination at test points or vents shall be minimized by downstream filters.

f. The bypass fluid or case drain flow on variable displacement pumps shall be filtered.

g. When the clogging of small orifices could cause a hazardous malfunction or failure of the system, they shall be protected by a filter element designed to prevent clogging of the orifice. Note that this includes servo valves.

h. Filters or screens shall not be used in suction lines of power pumps or hand pumps of safety critical systems.

i. Air filters shall be specified for hydraulic reservoir air pressurization circuits and locate air filters to protect the pressure regulating equipment from contamination.

j. Dry compressed air shall be specified for hydraulic reservoir pressurization.

k. A moisture removal unit shall be specified to protect the pressure regulation lines and equipment.

l. Unpressurized Reservoirs. Unpressurized hydraulic reservoirs shall have filters and desiccant units at the breather opening to preclude introduction of moisture and contaminants into the reservoir.

3.12.5.1.11 Bleed Ports.

a. Where necessary, bleed ports shall be provided to remove accumulations of residue or contaminants.

b. High point bleed ports shall be provided where necessary for removal of trapped gases.

c. The bleed valve shall be directed away from operating personnel and possible ignition sources.

d. Components, cavities, or lines that can be isolated shall be equipped with bleed valves that can be used to release retained pressure, or will indicate that continued pressure exists in the system.

e. Bleed valves used for reducing pressure on systems containing hazardous fluids shall be routed to a safe disposal area.

f. Auxiliary Bleed Ports

1. Auxiliary bleed ports shall be provided where necessary to allow bleed off for safety purposes.

2. Bleeder valves shall be located so that they can be operated without removal of other components, and shall permit the attachment of a hose to direct the bleed-off fluid into a container.

g. Filler Cap Bleed. Reservoir filler caps shall include design provisions that shall automatically bleed the reservoir on opening, so that possible ullage pressure cannot impart hazardous kinetic energy to either the filler caps, the fluid in the reservoir, or the system.

3.12.5.1.12 Control Devices.

a. Safety critical pressure systems incorporating two or more directional control valves shall be designed to preclude the possibility of inadvertently directing the flow or pressure from one valve into the flow path or pressure path intended for another valve, with any combination of valve settings possible in the total system.

b. Control devices shall be designed to prevent overtravel or undertravel that may contribute to a hazardous condition, or damage to the value.

c. All pressure and volume controls shall have stops, or equivalent, to prevent settings outside their nominal safe working ranges.

d. Control components that have integral manually operated levers and stops capable of withstanding the following limit torques.

Lever Radius (R)	Design Torque

Less than 3 in.	50 x R lb-in.
3 to 6 in.	75 x R lb-in.
Over 6 in.	150 x R in-in.

3.12.5.1.13 Manually Operated Levers.

a. Components that have integrated manually operated levers shall provide levers and stops capable of withstanding the limit torques specified by MIL-STD-1472.

b. Levers and stops shall be provided on remote controls capable or withstanding a limit torque of 1800 lb-in.

c. Because jamming is possible, sheathed flexible actuators shall not be used for valve controls in safety critical pressure systems; for example, push-pull wires, torque wires that are sheathed are not acceptable.

3.12.5.1.14 Accumulators.

a. Accumulators shall be designed in accordance with the pressure vessel standards for ground systems and locate for minimal probability of mechanical damage and for minimum escalation of material damage or personnel injury in the event of a major failure such as tank rupture.

b. Accumulator gas pressure gauges shall not be used to indicate system pressure for operational or maintenance purposes.

c. Gas type and pressure level shall be posted on, or immediately adjacent to the accumulator.

3.12.5.1.15 Flex Hose.

a. Flex hose shall be used between any two connections where relative motion can be expect-ed to fatigue metal tube or pipe.

b. Flex hose installation shall be designed to avoid abrasive contact with adjacent structure or moving parts.

c. Rigid supports shall not be used on flex hose.

d. Flex hose installation that are six feet long or greater shall be included so that restraint is provided on both the hose and adjacent structure at no greater than six-foot intervals and at each end to prevent whiplash in the event of a burst.

e. Restraining devices shall be designed and demonstrated to contain a force not less than 1.5 x open line pressure force. (See Table 3-3)

f. The design safety factor shall not be less than 3.

g. Sand or shot bags placed on top of flexible hose is not an acceptable restraint.

h. Hose clamp-type restraining devices shall not be used.

i. Flex hose installations shall be designed to produce no stress or strain of any nature in the hard lines or components.

j. Stresses induced because of dimensional changes caused by pressure or temperature variations or torque forces induced in the flex hose shall be included.

k. Temporary installations using chains or cables anchored to substantial fixed points, lead ingots, or other weights, are acceptable if they meet the requirements of Section 3.12.5.1.2.a.

l. Flex hose shall be protected from kinking or abrasive chafing from the restraining device or damage from adjacent structure or moving parts that may cause reduction in strength.

3.12.5.1.16 Qualification Test Requirements. Qualification tests are not required on lines and fittings. Internal/external pressure testing shall be conducted on all other pressure components to demonstrate no failure at the design burst pressure.

Table 3-3
Open Line Force Calculation Factor

Diameter Opening (inch)	Calculated Force Factor for each psi of Source Pressure (lb)
1/8	0.18506
1/5	0.2832
3/8	0.3814
1/2	0.4796
5/8	0.5777
3/4	0.6759
7/8	0.7741
1	0.8723

Note: To calculate the force acting on line opening, select applicable diameter and multiply right-hand column by the source pressure (psi).

Seamless lines, tubing and pipe are exempt.

3.12.5.1.17 Acceptance Test Requirements.

a. Testing Flight Hardware Pneumatic Components Prior to Assembly

1. All other pressurized components such as valves, pipe, tubing, and pipe and tube fittings shall be hydrostatically proof tested to a minimum of 1.5 times the component MAWP for a minimum of 5 min.

2. Proof testing shall demonstrate that the components will sustain proof pressure levels without distortion, damage, or leakage.

3. Both the inlet and discharge sides of a relief valve shall be proof tested. **NOTE**: When the discharge side has a lower pressure rating than the inlet, they are to be proof tested independently.

4. The following inspections shall be performed after proof testing:

(a) Mechanical components such as valves and regulators shall be inspected for external deformation, deterioration, or damage.

(b) Damaged, distorted, or deteriorated parts shall be rejected and replaced and the test repeated.

5. Functional and leak tests shall be performed at the component MAWP after the proof test.

6. Pneumatic pressure system components shall undergo sufficient qualification and acceptance testing to demonstrate that the system and components meet design and safety requirements when subjected to prelaunch and launch environments such as vibration, shock, acceleration, and temperature.

7. Test plans and test reports shall be made available to Range Safety.

8. Pressure relief valves shall be tested for proper setting and flow capacity prior to installation and first use on the Ranges.

9. Pressure gauges and transducers shall be hydrostatically tested to a minimum of 1.5 times the system MOP/MEOP.

10. Pressure gauges and transducers shall be calibrated prior to installation and periodically thereafter.

11. Components may be initially hydrostatically proof tested after being assembled into a subsystem or system to 1.5 times the system MOP. **NOTE:** This approach shall be approved by Range Safety.

12. Pneumatic proof testing to a proof pressure of 1.25 times MAWP is permissible only if hydrostatic proof testing is impractical, impossible, or will jeopardize the integrity of the system or system element. **NOTE:** Prior approval for pneumatic proof testing at the Ranges shall be obtained from Range Safety.

b. Testing Flight Hardware Pneumatic Systems After Assembly. All newly assembled pneumatic pressure systems shall be hydrostatically tested to 1.5 times MOP/MEOP prior to use. **NOTE 1**: MOP here refers to the maximum operating pressure that personnel are exposed to. **NOTE 2**: Where this is not possible, Range Safety will determine the adequacy of component testing and alternate means of testing the assembled system.

c. Leak Tests. All newly assembled pressure systems shall be leak tested at the system MOP/MEOP prior to first use at the Ranges. **NOTE:** This test shall be conducted at the Ranges unless prior approval from Range Safety has been obtained. Minimum test requirements are as follows:

1. The gas used during the leak test shall be the same as the system fluid media except that for hazardous gas systems, a system compatible non-hazardous gas may be used that has a density as near as possible to the system fluid; for example, helium should be used to leak test a gaseous hydrogen system.

2. Mechanical connections, gasketed joints, seals, and weld seams, and other items shall be visually bubble tight for a minimum of 1 min when an approved leak test solution is applied.

3. Alternate methods of leak testing such as the use of portable mass spectrometers may be specified when required on a case-by-case basis.

d. System Validation and Functional Tests. All newly assembled pressure systems shall have a system validation test and a functional test of each component at system MOP prior to first use at the Ranges. **NOTE**: These tests shall be conducted at the Ranges unless prior approval from Range Safety has been obtained. Minimum test requirements are as follows:

1. These tests shall demonstrate the functional capability of all non-passive components such as valves, regulators, and transducers.

2. All prelaunch operational sequences for the system shall be executed.

3. All parallel or series redundant components shall be individually tested to ensure single fault tolerant capabilities are functional prior to launch.

4. All shutoff and block valves shall be leak checked downstream to verify their shutoff capability in the CLOSED position.

e. Bonding and Grounding Tests. All newly assembled pressure systems containing flammable and combustible fluids shall be tested to verify that the requirements of the **Flight Hardware Pressure System Bonding and Grounding** section of this Chapter have been met.

f. Test Requirements for Modified and Repaired Flight Hardware Pneumatic Systems

1. Any pressure system element, including fittings or welds, that has been repaired, modified, or possibly damaged subsequent to having been proof tested, shall be retested at proof pressure prior to its normal use.

2. A modified or repaired pressure system shall be leak tested at the system MOP/MEOP prior to its normal use. **NOTE**: This test shall be conducted at the Ranges unless prior approval from Range Safety has been obtained.

g. A modified or repaired pressure system shall be revalidated and functionally tested at the system MOP prior to its normal use.

h. If any pressure system element such as valve, regulator, gauges, or tubing has been disconnected or reconnected for any reason, the affected system or subsystem shall be leak tested at MOP/MEOP.

3.12.5.2 Hazardous Fluid Systems Component Requirements, including Hypergolic, Cryogenic, and Hydraulic Systems

Hypergolic and cryogenic components are required to meet the requirements in Sections 3.12.6, 3.12.7, 3.12.8 and 3.12.9 in addition to the following:

a. Cycling capability for safety critical components shall be not less than 400 percent of the total number of expected cycles, including system tests, but not less than 2,000 cycles.

b. For service above a temperature of 160°F, an additional cycling capability equivalent to the above shall be required as a maximum.

c. Safety critical actuators shall have positive mechanical stops at the extremes of safe motion.

d. Fluid reservoirs and supply tanks shall be equipped with shutoff valves, operable from a relatively safe location in the event of a hydraulic system emergency.

e. Shuttle valves shall not be used in safety critical hydraulic systems where the event of a force balance on both inlet ports may occur, causing the shuttle valve to restrict flow from the outlet port.

f. Systems incorporating accumulators shall be interlocked to either vent or isolate accumulator fluid pressure when power is shutoff.

g. Adjustable orifice restrictor valves shall not be used in safety critical systems.

h. When two or more actuators are mechanically tied together, only one lock valve shall be used to lock all the actuators.

i. Lock valves shall not be used for safety critical lockup periods likely to involve extreme temperature changes, unless fluid expansion and contraction effects are safely accounted for.

j. Reservoir

1. Whenever possible, the hydraulic reservoir should be located at the highest point in the system.

2. If this is not possible in safety critical systems, procedures shall be developed to detect air in actuators or other safety critical components and to ensure that the system is properly bled prior to each use.

k. Systems installations shall be limited to a maximum pressure of 15,000 psig. **NOTE:** There is not intent to restrain development of systems capable of higher pressures, however, the employment of such systems must be preceded by complete development and qualification that includes appropriate safety tests.

l. The inlet pressure of pumps in safety critical systems shall be specified to prevent cavitation effects in the pump passages or outlets.

m. Fluid Column. Safety critical systems shall have positive protection against breaking the fluid column in the suction line during standby.

n. Systems for primary flight control of manned vehicles shall have redundant features for all major aspects of operation and control and be essentially independent of systems non-critical to safety. **NOTE:** Provision may be made for a safety critical systems to draw power from a non-critical system, provided that no single failure can cause loss of both systems because of this connection.

o. Systems that provide for manual takeover shall automatically disengage or allow by-pass of the act of manual takeover.

p. Safety critical systems or alternate by-pass systems provided for safety shall not be rendered inoperative because of back pressure under any set of conditions.

q. The system shall be designed so that a lock resulting from an unplanned disconnection of a self-seating coupling or other component shall not cause damage to the system or to adjacent property, or injury to personnel.

r. Systems employing power operated pumps shall include a pressure regulating device and an independent safety relief valve.

s. Thermal Pressure Relief.

1. Thermal expansion relief valves shall be installed as necessary to prevent system damage from thermal expansion of hydraulic fluid, as in the event of gross overheating.

2. Internal valve leakage not be considered an acceptable method of providing thermal relief.

3. Thermal relief valve setting shall not exceed 150 psi above the value for system relief valve setting.

4. Vents shall outlet only to areas of relative safety from fire hazard.

5. Hydraulic blow-out fuses (soft plugs) shall not be used in systems having temperatures above 160°F.

t. Pressure relief valves shall be located in the systems wherever necessary to ensure that the pressure in any part of a power system shall not exceed the safe limit above the regulated pressure of the system.

3.12.6 Flight Hardware Pneumatic System Design Requirements

This section presents specific requirements for the design of flight hardware pneumatic systems and specific pneumatic system components.

3.12.6.1 Flight Hardware Pneumatic System Piping

a. NPT connectors shall not be used in hazardous pressure system piping.

b. Socket welded flanges shall not be used in hazardous pressure system piping.

c. All piping and fitting welds shall be 100 percent radiographically inspected.

3.12.6.2 Flight Hardware Pneumatic System Tubing

All tubing and fitting welds shall be 100 percent radiographically inspected before and after the proof test.

3.12.6.3 Flight Hardware Pneumatic System Regulators

a. Regulators shall be selected so that their working pressure falls within the center 50 percent of their total pressure range if it is susceptible to inaccuracies or creep at either end of its pressure range.

b. Pressure regulator actuators shall be capable of shutting off the fluid when the system is at the maximum possible flow and pressure.

c. Designs using uncontained seats are unacceptable.

d. Systems that contain regulators that are remotely operated during prelaunch operations shall be designed to be fail-safe if pneumatic or electric control power to the regulator is lost.

3.12.6.4 Flight Hardware Pneumatic System Valves

a. Valve actuators shall be operable under maximum design flow and pressure.

b. Manually operated valves shall be designed so that overtorquing the valve stem cannot damage soft seats to the extent that seat failure occurs.

c. Designs using uncontained seats are prohibited.

d. Valves that are not intended to be reversible shall be designed or marked so that they will not be connected in a reverse mode.

e. All electrical control circuits for remotely actuated valves shall be shielded or otherwise protected from hazardous stray energy.

f. Remotely controlled valves shall provide for remote monitoring of OPEN and CLOSED positions during prelaunch operations.

g. Systems that contain remotely operated valves shall be designed to be fail-safe if pneumatic or electric control power to the valve is lost during prelaunch operations.

h. Check valves shall be provided where back flow of fluids would create a hazard.

i. Special care shall be taken in the design of oxygen systems to minimize the heating effect due to rapid increases in pressure. **NOTE**: Fast opening valves that can produce high velocity kinetic effects and rapid pressurization shall be avoided.

j. Valve stem travel on manual valves shall be limited by a positive stop at each extreme position.

k. The application or removal of force to the valve stem positioning device shall not cause disassembly of the pressure containing structure of the valve.

3.12.6.5 Flight Hardware Pneumatic System Pressure Indicating Devices

a. A pressure indicating device shall be located on the downstream side of each pressure regulator, and on any storage system.

b. These pressure indicating devices shall be designed to be remotely monitored during prelaunch operations.

3.12.6.6 Flight Hardware Pneumatic System Flexible Hoses

a. Hoses shall be used only when required to provide for movement between interconnecting gas lines when no other feasible means is available.

b. Flex hose installation shall be designed to avoid abrasive contact with adjacent structures or moving parts.

c. Flex hose assemblies shall not be installed in a manner that will place a mechanical load on the hose or hose fittings to the extent that will degrade hose strength or cause the hose fitting to loosen.

d. Flexible hose shall not be supported by rigid lines or components if excessive loads from flex hose motion can occur.

e. Flex hoses shall not be exposed to temperatures that exceed the rated temperature of the hose.

f. Flex hoses that are permitted to pass close to a heat source shall be protected.

g. The bend radius of flex hoses shall be designed to be no less than the safe minimum bend radius recommended in authoritative specifications for the particular hose.

h. All flexible hoses that are not lined shall be subjected to a flow induced vibration analysis. **NOTE:** A guidance document for performing this analysis is MSFC 20MO2540.

3.12.6.7 Flight Hardware Pneumatic System Pressure Relief Devices

a. Pressure relief devices shall be installed on all systems having an on-board pressure source that can exceed the MAWP of any component downstream of that source unless the system is single fault tolerant against overpressurization during prelaunch operations.

b. Flight systems that require on-board pressure relief capability shall be designed to the following minimum requirements:

1. The pressure relief device shall be installed as close as is practical downstream of the pressure reducing device or source of pressure such as compressor and gas generator.

2. Pressure relief devices should be set to operate at a pressure not to exceed 110 percent of the system MOP.

3. The relieving capacity of the relief device shall be equal to or greater than the maximum flow capability of the upstream pressure reducing device or pressure source and should prevent the pressure from rising more than 20 percent above the system MOP.

4. The relief device vent outlet piping shall be sized to prevent excessive back pressure from adversely affecting the function of the relief device.

5. All relief devices and associated piping shall be structurally restrained to minimize any thrust effects on the pressure system vessels or piping.

6. The effects of the discharge from relief devices shall be assessed and analyzed to ensure that operation of the device will not be hazardous to personnel or equipment. **NOTE**: Items to be analyzed are thrust loads, noise, impingement of high velocity gas or entrained particles, toxicity, oxygen enrichment, and flammability.

7. All pressure relief devices shall be vented separately unless the following can be positively demonstrated:

(a) The creation of a hazardous mixture of gases in the vent system and the migration of hazardous substances into an unplanned environment is impossible.

(b) The capacity of the vent system is adequate to prevent a pressure rise of more than 20 percent above MOP when all attached pressure relief devices are wide open and the system is at full pressure and volume generating capacity.

8. No obstructions shall be placed downstream of the relief device.

9. Relief devices shall be located so that other components cannot render them inoperative.

3.12.6.8 Flight Hardware Pneumatic System Vents

a. Pressure systems shall be designed so that pressure cannot be trapped in any part of the system without vent capability.

b. Vent system outlets should be in a location normally inaccessible to personnel or shall be conspicuously identified.

c. Vent outlets shall be protected against rain intrusion and entry of birds, insects, and animals.

d. Oxidizer and fuel vent outlets to the atmosphere shall be separated sufficiently to prevent mixing of vented fluids.

e. All vent outlets shall be designed to prevent accumulation of vented gases in dangerous con-concentrations (oxygen rich) in areas frequented by unprotected personnel.

f. Hydrogen vents shall discharge to atmosphere through an approved burner.

g. Special attention shall be given to the design of vent line supports at vent outlets due to potential thrust loads.

h. Each line venting into a multiple use vent system shall be protected against back pressurization by means of a check valve if the upstream system cannot withstand the back pressure or where contamination of the upstream system cannot be tolerated.

3.12.7 Flight Hardware Hydraulic System Design Requirements

Flight Hardware Hydraulic Systems shall meet the minimum design fabrication and test requirements of Section 3.12.5.2 in addition to the following.

3.12.7.1 Flight Hardware System General Design Requirements

a. Where necessary, hydraulic system low-points shall be provided a drain fitting (bleed ports) to allow draining of condensates or residue for safety purposes. **NOTE**: Entrapped air, moisture, and cleaning solvents are examples of foreign substances that may be hazardous to the system, component, or control equipment.

b. Bleed ports shall be located so that they can be operated without removal of other components and will permit the attachment of a hose to direct the bleed off material into a container away from the positions of the operators.

c. Test points shall be provided on hydraulic systems so that disassembly for test is not required.

d. Test points shall be easily accessible for the attachment of ground test equipment.

e. For all power-generating components, pump pulsations shall be controlled to a level that does not adversely affect system tubing, components, and support installation.

f. Where system leakage can expose hydraulic fluid to potential ignition sources, fire resistant or flameproof hydraulic fluid shall be used.

3.12.7.2 Flight Hardware Hydraulic Accumulators and Reservoirs

All accumulators and reservoirs that are pressurized with gas to pressures greater than 100 psig shall be designed in accordance with Section 3.12.2.

3.12.7.3 Flight Hardware Hydraulic System Pressure Indicating Devices

a. A pressure indicating device shall be located on any pressurized storage system with a pressure greater than 100 psig.

b. These devices shall be designed to be remotely monitored during prelaunch operations.

3.12.7.4 Flight Hardware Hydraulic System Pressure Relief Devices

a. Pressure relief devices shall be installed on all hydraulic systems having an on-board pressure source that can exceed the MAWP of any component downstream of that source unless the system is single fault tolerant against overpressurization during prelaunch operations.

b. Flight systems that require on-board pressure relief capability shall meet the following minimum requirements:

1. The pressure relief device shall be installed as close as practical downstream of the pressure sources such as pumps, turbines, or gas generators.

2. Pressure relief devices should be set to operate at a pressure not to exceed 110 percent of the system MOP.

3. The relieving capacity of the relief device shall be equal to or greater than the maximum flow capability of the upstream pressure source and should prevent the pressure from rising more than 20 percent above the system MOP.

4. The effects of discharge from relief devices shall be assessed and analyzed to ensure that operation of the device will not be hazardous to personnel or equipment. **NOTE**: Items to be analyzed include thrust loads, toxicity, combustibility, flammability, and others as necessary.

5. Relief devices shall be located so that other components cannot render them inoperative.

6. No obstructions shall be placed downstream of the relief valve or burst disk outlet.

3.12.7.5 Flight Hardware Hydraulic Vent and Drain Systems

Hydraulic systems shall be designed so that pressure and fluids cannot be trapped in any part of the system without vent and/or drain capability.

3.12.7.6 Testing Flight Hardware Hydraulic System Components Prior to Assembly

a. All accumulators and reservoirs pressurized with gas to pressures greater than 100 psig shall be qualification tested in accordance with Section 3.12.2.4.1 and acceptance tested in accordance with Section 3.12.2.4.2.

b. All other hydraulic system components such as valves, pipe, tube, and pipe and tube fittings shall be hydrostatically proof tested to a minimum of 1.5 times the component MAWP for a minimum of 5 min.

c. Proof testing shall demonstrate that the components will sustain proof pressure levels without distortion, damage, or leakage.

d. Both the inlet and discharge sides of a relief valve shall be proof tested.

e. When the discharge side of a relief valve has a lower pressure rating than the inlet side, they shall be proof tested independently.

f. Pressure relief valves shall be tested for proper setting and flow capacity prior to installation and first use on the Ranges.

g. Pressure gauges and transducers shall be hydrostatically tested to a minimum of 1.5 times the system MOP.

h. Pressure gauges and transducers shall be calibrated prior to installation and periodically thereafter.

i. Components may be initially hydrostatically proof tested after being assembled into a subsystem or system to 1.5 times the system MOP. **NOTE**: This approach shall be approved by Range Safety.

3.12.7.7 Testing Flight Hardware Hydraulic Systems After Assembly

3.12.7.7.1 Hydrostatic Tests. All newly assembled hydraulic pressure systems shall be hydrostatically tested to 1.5 times the system MOP prior to use. **NOTE 1**: MOP here refers to the maximum operating pressure that personnel are exposed to. **NOTE 2**: Where this is not possible, Range Safety will determine the adequacy of component testing and alternate means of testing the assembled system.

3.12.7.7.2 Leak Tests. All newly assembled hydraulic systems shall be leak tested at the system MOP after the proof test and prior to first use at the Ranges. **NOTE:** This test shall be conducted at the Ranges unless prior approval from Range Safety has been obtained. Minimum test requirements are as follows:

a. The fluid used during the leak test shall be the same as the system fluid media.

b. All mechanical joints such as gasketed joints, seals, threaded joints, and weld seams shall be inspected for leaks while monitoring for any pressure decay.

c. All shutoff and block valves shall be leak checked downstream to verify their shutoff capability in the CLOSED position.

3.12.7.7.3 System Validation and Functional Tests.

a. All newly assembled hydraulic systems shall have a system validation test and a functional test of each component at system MOP prior to first use at the Ranges. **NOTE:** These tests shall be conducted at the Ranges unless prior approval from Range Safety has been obtained.

b. Minimum test requirements are as follows:

1. These tests shall demonstrate the functional capability of all components.

2. All prelaunch operational sequences for the system shall be executed.

3.12.7.8 Testing Modified and Repaired Flight Hardware Hydraulic Systems

a. Any hydraulic system element, including fittings or welds, that has been repaired, modified, or possibly damaged subsequent to having been proof tested shall be retested at proof pressure prior to its normal use.

b. A modified or repaired hydraulic system shall be leak tested at the system MOP prior to its normal use. **NOTE**: This test shall be conducted at the Ranges unless prior approval from Range Safety has been obtained.

c. A modified or repaired hydraulic system shall be revalidated and functionally tested at the system MOP prior to its normal use.

d. If any hydraulic system element such as valves, regulators, gauges, or tubing has been disconnected or reconnected for any reason, the affected system or subsystem shall be leak tested at MOP.

3.12.8 Flight Hardware Hypergolic Propellant System Design and Test Requirements

3.12.8.1 Flight Hardware Hypergolic Propellant System General Design Requirements

a. Propellant systems shall have low point drain capability.

b. Low point drains shall be accessible and located in the system to provide the capability of removing propellant from the tanks, piping, lines, and components at all times after loading.

c. Propellant systems shall be designed to be flushed and purged with inert fluids.

d. For prelaunch failure modes that could result in a time-critical emergency, provision shall be made for automatic switching to a safe mode of operation. **NOTE**: Caution and warning signals shall be provided for these time-critical functions.

e. Hypergolic propellant systems shall also comply with the pneumatic system requirements of Section 3.12.6.

f. Items used in any fuel or oxidizer system shall not be interchanged after exposure to the respective media.

g. Bi-propellant systems shall have the capability of loading the fuel and oxidizer system one at the time.

h. Hypergolic propellant (liquid or gas) migration into an associated pneumatic system shall be controlled. **NOTE**: The pneumatic system should be compatible with all of the hypergolic propellants served by the pneumatic supply.

3.12.8.2 Flight Hardware Hypergolic Propellant System Piping and Tubing

a. NPT connectors shall not be used in hypergolic system piping and tubing.

b. Socket weld flanges shall not be used in hypergolic system piping.

c. All pipe and tube welded joints shall be 100 percent radiographically inspected before and after the acceptance proof test.

3.12.8.3 Flight Hardware Hypergolic Propellant System Valves

a. Valve actuators shall be operable under maximum design flow and pressure.

b. Flow control valves shall be designed to be fail-safe if pneumatic or electric control power is lost during prelaunch operations.

c. Check valves shall be provided where back flow of fluids would create a hazard.

d. Valve connectors and connections shall be designed, selected, or located, (or as a last resort, marked) to prevent connection to an incompatible system.

e. Remotely controlled valves shall provide for remote monitoring of OPEN and CLOSED positions during prelaunch operations.

f. All electrical control circuits for remotely actuated valves shall be shielded or otherwise protected from hazardous stray energy.

g. Designs using uncontained seats are prohibited.

h. Valves that are not intended to be reversible shall be designed or marked so that they will not be connected in a reverse mode.

i. Manually operated valves shall be designed so that overtorquing the valve stem cannot damage soft seats to the extent that seat failure occurs.

j. Valve stem travel on manual valves shall be limited by a positive stop at each extreme position.

k. The application or removal of force to the stem positioning device shall not cause disassembly of the pressure containing structure of the valve.

3.12.8.4 Flight Hardware Hypergolic Propellant System Pressure Indicating Devices

a. A pressure indicating device shall be located on any hypergolic storage vessel and on any section of the system where pressurized fluid can be trapped.

b. These pressure indicating devices shall be designed to be remotely monitored during prelaunch operations.

3.12.8.5 Flight Hardware Hypergolic Propellant System Flexible Hoses

a. Hoses shall be used only when required to provide movement between interconnecting fluid lines when no other feasible means is available.

b. Flex hose installation shall be designed to avoid abrasive contact with adjacent structures or moving parts.

c. Flexible hose shall not be supported by rigid lines or components if excessive loads from flex hose motion can occur.

d. Flex hose assemblies shall not be installed in a manner that will place a mechanical load on the hose or hose fittings to an extent that will degrade hose strength or cause the hose fitting to loosen.

e. The bend radius of flex hoses shall be designed to be no less than the safe minimum bend radius recommended in authoritative specifications for the particular hose.

f. Flex hoses shall not be exposed to temperatures that exceed the rated temperature of the hose.

g. Flex hoses that are permitted to pass close to a heat source shall be protected.

h. All flexible hoses that are not lined shall be subjected to a flow induced vibration analysis. **NOTE**: A guidance document for performing this analysis is MSFC 20MO2540.

3.12.8.6 Flight Hardware Hypergolic Propellant System Pressure Relief Devices

a. Pressure relief devices shall be installed on all systems having an on-board pressure source that can exceed the MAWP or MEOP of any component downstream of that source unless the system is single fault tolerant against overpressurization during prelaunch operation.

b. Flight systems that require on-board pressure relief capability shall be designed to the following minimum requirements:

1. The pressure relief device shall be installed as close as is practical downstream of the pressure reducing device or source of pressure such as a compressor or gas generator.

2. Pressure relief devices should be set to operate at a pressure not to exceed 110 percent of the system MOP/MEOP.

3. The relieving capacity of the relief device shall be equal to or greater than the maximum flow capability of the upstream pressure reducing device or pressure source and should prevent the pressure from rising more than 20 percent above the system MOP/MEOP.

c. The relief device vent outlet piping shall be sized to prevent excessive back pressure from adversely affecting the relief device function.

d. All relief devices and associated piping shall be structurally restrained to minimize any thrust effects to the pressure system vessels or piping.

e. The effects of the discharge from relief devices shall be assessed and analyzed to ensure that operation of the device will not be hazardous to personnel or equipment. **NOTE**: Items to be analyzed are thrust loads, toxicity, and flammability.

f. All pressure relief devices shall be vented separately unless the following criteria can be positively demonstrated:

1. The creation of a hazardous mixture of gases in the vent system and the migration of hazardous substances into an unplanned environment is impossible.

2. The capacity of the vent system is adequate to prevent a pressure rise more than 20 percent above MOP when all attached pressure relief devices are wide open and the system is at full pressure and volume generating capacity.

g. No obstructions shall be placed downstream of the relief device.

h. Relief devices shall be located so that other components cannot render them inoperative.

3.12.8.7 Flight Hardware Hypergolic Propellant Vent Systems

a. All hypergolic vent effluent resulting from routine operations shall be scrubbed and/or incinerated prior to venting to the atmosphere through vent stacks.

b. Hypergolic systems shall be designed so that vapors or liquids cannot be trapped in any part of the system without vent and/or drain capability.

c. Vent system outlets shall be in a location normally inaccessible to personnel and shall be conspicuously identified.

d. Vent outlets shall be protected against rain intrusion and entry of birds, insects, and animals.

e. Oxidizer and fuel vent outlets to the atmosphere shall be separated sufficiently to prevent mixing of vented fluids.

f. Special attention shall be given to the design of vent line supports at vent outlets due to potential thrust loads.

g. Each line venting into a multiple use vent system shall be protected against back pressurization by means of a check valve if the upstream system cannot withstand the back pressure or where contamination of the upstream system cannot be tolerated.

h. Pressure relief vents shall be designed and located so that vapors will not enter any inhabited areas.

i. Incompatible fluids shall not be discharged into the same vent or drain system.

j. Fuel and oxidizer vent systems shall be equipped with a means of purging the system with an inert gas to prevent explosive mixtures.

3.12.8.8 Testing Flight Hardware Hypergolic Propellant System Components Prior to Assembly

a. All hypergolic vessels shall be qualification tested in accordance with Section 3.12.2.2.3 and acceptance tested in accordance with Section 3.12.2.2.4.

b. All other pressurized components such as valves, pipe, tubing, and pipe and tube fittings shall be hydrostatically proof tested to a minimum of 1.5 times the component MAWP for a minimum of 5 min.

c. Proof testing shall demonstrate that the components will sustain proof pressure levels without distortion, damage, or leakage.

d. Both the inlet and discharge sides of a relief valve shall be proof tested. **NOTE:** When the discharge side of a relief valve has a lower pressure rating than the inlet, they shall be proof tested independently.

e. The following inspections shall be performed after proof testing.

1. Mechanical components such as valves and regulators shall be inspected for external deformation, deterioration, or damage.

2. Damaged, distorted, or deteriorated parts shall be rejected and replaced and the test repeated.

f. Functional and leak tests shall be performed at the component MAWP or MEOP after the proof test.

g. Pressure gauges and transducers shall be hydrostatically tested to a minimum of 1.5 times the system MOP.

h. Pressure gauges and transducers shall be calibrated prior to installation and periodically thereafter.

i. Pressure relief valves shall be tested for proper setting prior to installation and first use on the Ranges.

j. Components may be initially hydrostatically proof tested after being assembled into a subsystem or system to 1.5 times the system MOP/MEOP. **NOTE**: This approach shall be approved by Range Safety.

k. Pneumatic proof testing to a proof pressure of 1.25 times MAWP or MEOP is permissible only if hydrostatic proof testing is impractical, impossible, or will jeopardize the integrity of the system or system element. **NOTE**: Prior approval for pneumatic proof testing at the Ranges shall be obtained from Range Safety.

l. All hypergolic valves shall be tested for both internal and external leakage at their MAWP.

1. The normal leakage rate shall not exceed that detected by a volumetric bubble leak test conducted with a minimum 10 percent helium mixture.

2. Certain critical system components may require further elaborate testing (mass spectrometer) to verify leak rates not to exceed 1 x 10^{-6} cc/sec at standard temperature and pressure (STP) of helium gas.

3.12.8.9 Testing Flight Hardware Hypergolic Propellant Systems After Assembly

3.12.8.9.1 Hydrostatic Tests. All newly assembled hypergolic propellant pressure systems shall be hydrostatically tested to 1.5 times MOP prior to use. **NOTE 1**: MOP here refers to the maximum operating pressure that personnel are exposed to. **NOTE 2**: Where this is not possible, Range Safety will determine the adequacy of component testing and alternate means of testing the assembled system.

3.12.8.9.2 Leak Tests.

a. Pneumatic leak testing at system MOP/-MEOP of all completely assembled and cleaned vessel pipe and tubing sections, with components installed, shall be completed prior to introduction of propellant.

b. Minimum test requirements are as follows:

1. Test gas should use a minimum volume of 10 percent helium.

2. All mechanical joints such as gasket joints, seals, and threaded joints and weld seams shall be visually bubble tight, using approved soap solution and techniques.

3. The functional validity of installed block valves should be checked by incrementally venting downstream sections and pin hole leak checking. **NOTE**: This test shall be conducted at the Ranges unless prior approval from Range Safety has been obtained.

c. When required, alternate methods of leak testing such as the use of portable mass spectrometers may be specified on a case-by-case basis.

3.12.8.9.3 System Validation and Functional Tests.

a. All newly assembled pressure systems shall have a system validation test and a functional test of each component performed at system MOP/MEOP prior to first use on the Ranges. **NOTE:** These tests shall be conducted at the Ranges unless prior approval from Range Safety has been obtained.

b. Minimum test requirements are as follows:

1. These tests shall demonstrate the functional capability of all non-passive components such as valves, regulators, and transducers.

2. In addition, all prelaunch operational sequences for the system shall be executed.

3. All parallel or series redundant components shall be individually tested to ensure single fault tolerant capabilities are functional prior to launch.

4. All shutoff and block valves shall be leak checked downstream to verify their shutoff capability in the CLOSED position.

3.12.8.9.4 Bonding and Grounding. All newly assembled pressure systems containing flammable and combustible fluids shall be tested to verify that the bonding and grounding requirements of the **Flight Hardware Pressure System Bonding and Grounding** section of this Chapter have been met.

3.12.8.10 Testing Modified and Repaired Flight Hardware Hypergolic Propellant Systems

a. Any hypergolic system elements including fittings or welds that have been repaired, modified, or possibly damaged after having been proof tested shall be retested at proof pressure prior to their normal use.

b. A modified or repaired hypergolic system shall be leak tested at the system MOP/MEOP prior to its normal use. **NOTE**: This test shall be conducted at the Ranges unless prior approval from Range Safety has been obtained.

c. A modified or repaired hypergolic system shall be revalidated and functionally tested at the system MOP/MEOP prior to its normal use.

d. If any hypergolic system elements such as valves, gauges, and tubing have been disconnected or reconnected for any reason, the affected system or subsystem shall be leak tested at MOP/MEOP.

3.12.9 Flight Hardware Cryogenic Systems Design and Test Requirements

3.12.9.1 Flight Hardware Cryogenic System General Design Requirements

a. Propellant systems shall have low point drain capability.

1. Low point drains shall be accessible and located in the system to provide the capability of removing propellant from the tanks, piping, lines, and components.

2. In addition, the LH_2 system shall be designed to be purged with inert fluids.

b. Bi-propellant systems shall have the capability of loading the fuel and oxidizer one at the time.

c. For prelaunch failure modes that could result in a time-critical emergency, provision shall be made for automatic switching to a safe mode of operation. **NOTE**: Caution and warning signals shall be provided for these time-critical functions.

d. Pneumatic systems servicing cryogenic systems shall comply with the pneumatic pressure system requirements of the **Flight Hardware Pneumatic Systems** section of this Chapter.

e. Cryogenic systems shall be designed to control liquefaction of air.

f. For systems requiring insulation, nonflammable materials shall be used in compartments or spaces where fluids and/or vapors could invade the area.

g. Vacuum-jacketed systems shall be capable of having the vacuum verified.

h. Purge gas for LH_2 and cold GH_2 lines should be gaseous helium (GHe).

i. Precautions shall be taken to prevent cross mixing of media through common purge lines by use of check valves to prevent back flow from a system into a purge distribution manifold.

j. Titanium and titanium alloys shall not be used where exposure to GOX (cryogenic) or LOX is possible.

3.12.9.2 Flight Hardware Cryogenic System Vessels and Tanks

Cryogenic vessels and tanks shall be designed in accordance with the requirements identified in paragraph 3.12.2.

3.12.9.3 Flight Hardware Cryogenic System Piping and Tubing

a. The amount and type of thermal insulation (insulation material or vacuum-jacketed) shall be determined from system thermal requirements.

b. The use of slip-on flanges shall be avoided.

c. Flanged joints in LH_2 systems shall be seal welded.

d. Flanged joint gaskets are not to be reused.

e. Cryogenic systems shall provide for thermal expansion and contraction without imposing excessive loads on the system. **NOTE**: Bellows, reactive thrust bellows, or other suitable load relieving flexible joints may be used.

f. All pipe and tube welds shall be 100 percent radiographically inspected before and after the acceptance proof test. **NOTE**: The accept and reject criteria shall be submitted to Range Safety for review and approval.

3.12.9.4 Flight Hardware Cryogenic System Valves

a. Cryogenic systems shall be designed to ensure icing does not render the valve inoperable.

b. Remotely controlled valves shall provide for remote monitoring of OPEN and CLOSED position.

c. Remotely operated valves shall be designed to be fail-safe if pneumatic or electric control power is lost during prelaunch operations.

d. All electrical control circuits for remotely actuated valves shall be shielded or otherwise protected from hazardous stray energy.

e. Manually operated valves shall be designed so that overtorquing the valve stem cannot damage seats to the extent that seat failure occurs.

f. Valve stem travel on manual valves shall be limited by a positive stop at each extreme position.

g. The application or removal of force to the stem positioning device shall not cause disassembly of the pressure containing structure of the valve.

h. Manual or remote valve actuators shall be operable under maximum design flow and pressure.

i. Valves that are not intended to be reversible shall be designed or marked so that they will not be connected in a reverse mode.

j. Stem position local or remote indicators shall sense the position of the stem directly, not the position of the actuating device.

3.12.9.5 Flight Hardware Cryogenic System Pressure Indicating Devices

a. A pressure indicating device shall be located on any cryogenic vessel and/or tank and on any section of the system where cryogenic liquid can be trapped.

b. These pressure indicating devices shall be designed to be remotely monitored during prelaunch operations.

3.12.9.6 Flight Hardware Cryogenic System Flexible Hoses

a. Hoses shall be used only when required to provide for movement between interconnecting cryogenic lines if no other feasible means are available.

b. Flex hose installation shall be designed to avoid abrasive contact with adjacent structures or moving parts.

c. Flexible hose shall not be supported by rigid lines or components if excessive loads from flex hose motion can occur.

d. Flex hose assemblies shall not be installed in a manner that will place a mechanical load on the hose or hose fittings to an extent that will degrade hose strength or cause the hose fitting to loosen.

e. The bend radius of flex hoses shall be designed to be no less than the safe minimum bend radius recommended in authoritative specifications for the particular hose.

f. All flexible hoses that are not lined shall be subjected to a flow induced vibration analysis. **NOTE:** A guidance document for performing this analysis is MSFC 20MO2540.

3.12.9.7 Flight Hardware Cryogenic System Pressure Relief Devices

a. All cryogenic vessels and tanks shall be protected against overpressure by means of at least one pressure relief valve.

b. Minimum design requirements are as follows:

1. The pressure relief device shall be installed as close as practical to the cryogenic vessel or tank.

2. Pressure relief valves shall be set to operate at pressures determined on a case-by-case basis by the Range User.

3. The relieving capacity of the relief valve shall be determined on a case-by-case basis by the Range User.

c. All pressure relief devices shall be vented separately unless the following can be positively demonstrated:

1. The creation of a hazardous mixture of gases in the vent system and the migration of hazardous substances into an unplanned environment is impossible.

2. The capacity of the vent system is adequate to prevent a pressure rise more than 20 percent above MOP when all attached pressure relief devices are wide open and the system is at full pressure and volume generating capacity.

d. All relief devices and associated piping shall be structurally restrained to eliminate any deleterious thrust effects on cryogenic system vessels or piping.

e. The effects of the discharge from relief devices shall be assessed and analyzed to ensure that operation of the device will not be hazardous to personnel or equipment. **NOTE:** Items to be analyzed are thrust loads, impingement of high velocity gas or entrained particles, toxicity, oxygen enrichment, and flammability.

f. No obstructions shall be placed downstream of the relief valves.

g. Relief valves shall be located so that other components cannot render them inoperative.

3.12.9.8 Flight Hardware Cryogenic System Vents

a. GH_2 shall be vented to atmosphere through a burner system.

b. Cryogenic systems shall be designed so that fluids cannot be trapped in any part of the system without drain or vent (relief valve or vent valve) capability.

c. Each line venting into a multiple use vent system shall be protected against back pressurization by a check valve if the upstream system cannot withstand the back pressure or where contamination of the upstream system cannot be tolerated.

d. Vents shall be placed in a location normally inaccessible to personnel and at a height or location where venting will not normally be deposited into habitable spaces.

e. Each vent shall be conspicuously identified using appropriate warning signs, labels, and markings.

f. Vent outlets shall be located far enough away from incompatible propellant systems and incompatible materials to ensure no contact is made during vent operations.

g. Incompatible fluids shall not be discharged into the same vent or drain system.

h. Fuel vent systems shall be equipped with a means of purging the system with an inert gas to prevent explosive mixtures.

i. Vent outlets shall be protected against rain intrusion and entry of birds, insects, and animals.

j. Special attention shall be given to the design of vent line supports at vent outlets due to potential thrust loads.

3.12.9.9 Testing Flight Hardware Cryogenic System Components Prior to Assembly

a. All cryogenic vessels and tanks shall be qualification tested in accordance with Section 3.12.2.2.3 and acceptance tested in accordance with Section 3.12.2.2.4.

b. All other cryogenic components such as valves, pipe, tubing, and pipe and tube fittings shall be hydrostatically proof tested to a minimum of 1.5 times the component MAWP or MEOP at ambient temperatures for a minimum of 5 min.

c. Proof testing shall demonstrate that the components will sustain proof pressure levels without distortion, damage, or leakage.

d. Both the inlet and discharge sides of a relief valve shall be proof tested. **NOTE**: When the discharge side of a relief valve has a lower pressure rating than the inlet side, they are to be proof tested independently.

e. The following inspections shall be performed after proof testing:

1. Mechanical components such as valves shall be inspected for deformation, deterioration, or damage.

2. Damaged, distorted, or deteriorated parts shall be rejected and replaced and the test repeated.

f. Functional and leak tests shall be performed at the component MAWP or MEOP after the proof test.

g. Pressure relief valves shall be tested for proper setting and flow capacity prior to installation and first use on the Ranges.

h. Pressure gauges and transducers shall be hydrostatically tested to a minimum of 1.5 times the system MOP/MEOP.

i. Pressure gauges and transducers shall be calibrated prior to installation.

j. Components may be initially hydrostatically proof tested after being assembled into a subsystem or system to 1.5 times the system MOP/MEOP. **NOTE**: This approach shall be approved by Range

Safety.

k. Pneumatic proof testing to a proof pressure of 1.25 times MAWP/MEOP is permissible only if hydrostatic proof testing is impractical, impossible or will jeopardize the integrity of the system or system element. **NOTE**: Prior approval for pneumatic proof testing at the Ranges shall be obtained from Range Safety.

3.12.9.10 Testing Flight Hardware Cryogenic Systems After Assembly

a. All newly assembled pressure systems shall be hydrostatically tested to 1.5 times MOP/MEOP prior to use. **NOTE 1**: MOP here refers to the maximum operating pressure that personnel are exposed to. **NOTE 2**: Where this is not possible, Range Safety will determine the adequacy of component testing and alternate means of testing the assembled system.

b. All newly assembled cryogenic systems shall be leak tested.

c. The system shall be pressurized to the system MOP using gaseous helium for LH_2 systems and gaseous nitrogen for LOX systems.

d. Following the leak test, all newly assembled cryogenic systems shall have a system validation test performed at system MOP prior to first operational use at the Ranges.

e. Minimum test requirements are as follows:

1. The intended service fluid (LO_2, LH_2) shall be used as the validation test fluid.

2. The functional capability of all components and subsystems shall be validated.

3. All prelaunch operational sequences for the system shall be exercised, including emergency shutdown, safing, and unloading procedures.

4. Vacuum readings shall be taken and recorded of all vacuum volumes before, during, and after the test.

5. No deformation, damage, or leakage is allowed.

3.12.9.11 Testing Modified and Repaired Flight Hardware Cryogenic Systems

a. Any cryogenic system element, including fittings or welds, that has been repaired, modified, or possibly damaged subsequent to system leak test shall be retested.

b. The component retest sequence shall be as follows:

1. The component shall be hydrostatically proof test at ambient temperature to 1.5 times the component MAWP or MEOP.

2. The component shall be reinstalled into the cryogenic system and a leak check performed at system MOP or MEOP.

3. The functional capability of the modified and/or repaired component shall be revalidated using the intended service fluid at system MOP or MEOP.

c. If any cryogenic system elements such as valves, regulators, gauges, or pipes have been disconnected or reconnected for any reason, the affected connection shall be leak checked at MOP.

3.12.10 Flight Hardware Pressure Systems Data Requirements

This section lists the minimum data required to certify compliance with the design, analysis, and test requirements of the **Flight Hardware Pressure Systems and Pressurized Structures** section of this Chapter.

a. Data required by Sections 3.12.10.1 through 3.12.10.4 shall be incorporated into the MSPSP or submitted as a separate package when appropriate.

b. Data required by paragraph 3.12.10.5 shall be placed in a certification file to be maintained by the hazardous pressure system operator.

c. This data shall be reviewed and approved by Range Safety prior to the first operational use of hazardous pressure systems at the Ranges.

3.12.10.1 Flight Hardware Pressure Systems General Data Requirements

The following general flight hardware pressure systems data is required:

a. Hazard analysis of hazardous pressure systems in accordance with a jointly tailored Systems Safety Program (See Appendix 1B.)

b. The material compatibility analysis in accordance with the **Flight Hardware Pressure Systems Material Compatibility and Selection** and **Metallic Materials** sections of this Chapter

c. Physical and chemical properties and general characteristics of the propellant, test fluid, and gases. **NOTE:** Data shall be provided to both Range Safety, Bioenvironmental Engineering, Environmental Planning, 30 CEG and 30 SW/ET, as appropriate.

d. For hazardous propellants, fluids, and gases, the following data shall be submitted:

1. Specific health hazards such as toxicity and physiological effects

2. TLV, MAC for 8-hr day, 5-day week of continuous exposure

3. Emergency tolerance limits including length of time of exposure and authority for limits, such as the Surgeon General, NIOSH, or independent study

4. Maximum credible spill (volume and surface area) and supporting analyses

5. Description of hazards other than toxicity, such as flammability and reactivity

6. Identification of material incompatibility problems in the event of a spill

7. Personal protective equipment to be used in handling and using the propellants when this equipment will be used during an operation, and the manufacturer, model number, and other identifying data

8. Manufacturer, model number, specifications, operating limits, type of certification, and general description of vapor detecting equipment

9. Recommended methods and techniques for decontamination of areas affected by spills or vapor clouds and hazardous waste disposal procedures

3.12.10.2 Flight Hardware Pressure System Design Data Requirements

a. A schematic that presents the system in a clear and easily readable form, with complete subsystems grouped and labeled accordingly; nomenclature of each element should be made adjacent to or in the vicinity of each element.

b. The schematic or corresponding data sheet shall contain the following information:

1. Identification of all pressure system components such as valves, regulator, tubes, hoses, vessels, and gauges using standard symbols. **NOTE:** A legend is recommended and the original mechanical drawings should be referenced

2. MOP of all systems and subsystems at expected operating temperatures and identification of expected source pressures and expected delivery pressures

3. All relief valve pressure settings and flow rates

4. System fluid and maximum expected temperature

5. Pressure ranges of all pressure gauges

6. Pressure settings of pressure regulators

7. Charging pressure of reservoirs and vessels, their nominal capacities, and wall thickness

8. Pressure setting of all pressure switches

9. Nominal outside diameter and wall thickness of all tubing and piping

10. Flowpath through all components. **NOTE:** When the system is to be used in several operating modes, it is easier to provide a separate schematic that depicts flowpaths for each operating mode.

11. Identification of each component (reference designations) so that cross-reference between schematics and drawings and a pressure system component list or other documentation is possible

12. End-to-end electrical schematics of electrical and electronic components giving full functional data and current loads

13. Connections for testing or servicing

14. A narrative that provides the following information:

(a) Description of the system and its operating modes

(b) Discussion of operational hazards

(c) Discussion of accessibility of components

15. A sketch and/or drawing of the system that shows physical layout and dimensions shall be provided.

16. System information shall be placed in tables. (See Appendix 3A for guidance.)

3.12.10.3 Flight Hardware Pressure System Component Design Data

a. Identification of each component with a reference designation permitting cross-reference with the system schematic

b. MAWP for all pressure system components and the MOP the component shall see when installed in the system

c. Safety factors or design burst pressure for all pressure system components and identification of actual burst pressures, if available

d. Proof pressure for each system component and identification of the proof pressure the component will see after installation in the system, if applicable

e. Materials used in the fabrication of each element within the component including soft goods and other internal elements

f. Cycle limits if fatigue is a factor of the component

g. Temperature limits of each system component

h. Component information shall be placed in tables. (See Appendix 3A for guidance.)

3.12.10.4 Flight Hardware Pressure System Test Procedures and Reports

a. All test plans, test procedures and test reports required to be performed by the **Flight Hardware Pressure Systems** section of this Chapter shall be submitted to Range Safety for review and approval.

b. A list and synopsis of all hazardous pressure system operational procedures to be performed at the Ranges shall be provided.

3.12.10.5 Flight Hardware Pressure System Certification Files

a. Certification files shall be maintained and updated by the hazardous pressure system operator.

b. These files shall be located at the Ranges.

c. The certification file for each hazardous pressure system shall contain the data required in Sections 3.12.10.1 through 3.12.10.4 in addition to the following:

1. As applicable, stress, safe-life, fatigue, fracture mechanics analysis in accordance with sections 3.12.1.4.3, 3.12.1.5.4 and 3.12.1.5.5.

2. Specification drawings and documents for all components

3. If necessary, a cross-sectional assembly drawing of the component to assess the safety aspects of the internal elements

4. Certification that welding and weld NDE meet applicable standards and have been performed by certified personnel

5. Qualification and acceptance test plans and test reports

6. Certification documentation showing that vessels are designed, fabricated, and tested in accordance with Sections 3.12.1, 3.12.2 and 3.12.3.

7. Certification that all components, including pipe and tube fittings, have successfully passed a hydrostatic proof test

3.13 ORDNANCE SYSTEMS

3.13.1 Ordnance Hazard Classification

3.13.1.1 Ordnance General Classification

a. Ordnance items shall be assigned the appropriate DoD and United Nations (UN) hazard classification and storage compatibility group in accordance with DoD 6055.9-STD.

b. Items that have not previously been classified and cannot be classified based on similarity with previously classified items shall be tested in accordance with AFTO 11A-1-47/(NAVSEAINST 8020.3/TB700-2/DLAR 8220.1) and classified accordingly.

c. Ordnance items shall also have a DOT classification. **NOTE**: The Range User is responsible for obtaining DOT classification.

d. The Range User shall provide the DoD and DOT documentation demonstrating proper classification to Range Safety for review and approval prior to delivering ordnance to the Ranges.

3.13.1.2 Range Safety Ordnance Device and System Categorization

a. In addition to the requirements noted above, each ordnance device and system shall be classified as category A (hazardous) or B (non-hazardous) and the proposed classifications submitted to Range Safety for review and approval prior to delivering ordnance to the Ranges.

b. The following criteria shall be used to determine ordnance device and system hazard category:

1. Handheld Mode

(a) At least 1 percent of an ordnance item qualification lot or at 10 units shall be functioned to determine if the ordnance produces fragments, if the temperature rises above 260^{o}C, if the ordnance produces flame, or if the ordnance produces pressure in excess of 150 psig at the output end. **NOTE:** It is not the intention of this document to impose excessive test requirements. Similarities with previously tested items is often sufficient for categorization. If testing or analogy is not accomplished, the initiating device shall be treated as category A.

(b) If one or more of the tested units violate the criteria, the ordnance shall be considered category A in the handheld mode.

2. Assembled Mode

(a) An analysis of the ordnance system shall be performed to determine if its initiation is capable of causing injury or damage to DoD property on the Ranges.

(b) Tests will not be required for the assembled mode.

3.13.2 Ordnance System General Requirements

All the remaining parts of section 3.13 establish the design requirements for category A ordnance and ordnance systems during transportation, handling, storage, installation, testing, and connection on the

Ranges. Category B ordnance and ordnance systems do not have to meet requirements of EWR 127-1.

3.13.2.1 Ordnance Subsystem Identification

Ordnance systems include the following subsystems. All of these subsystems are subject to the design requirements in this section.

a. Power Source: The power source may be a battery, a dedicated power bus, or a capacitor.

b. Firing Circuit (the path between the power source and the initiating device): The firing circuit includes the electrical path and the optical path for laser initiated ordnance.

c. Control Circuit: The control circuit activates and deactivates the safety devices in the firing circuit.

d. Monitor Circuit: The monitor circuit monitors status of the firing circuits.

e. Initiating Device: The initiating device converts electrical, mechanical, or optical energy into explosive energy.

f. Receptor Ordnance: Receptor ordnance includes all ordnance items such as the explosive transfer system (ETS), separation charge, explosive bolt installed downstream of the initiating devices.

3.13.2.2 Preclusion of Inadvertent Firing

Ordnance devices and systems shall be designed to preclude inadvertent firing of any explosive or pyrotechnic components when subjected to environments such as shock, vibration, and static electricity encountered during ground processing.

3.13.2.3 Failure Mode Effects and Criticality Analysis

A Failure Mode Effects and Criticality Analysis (FMECA) shall be performed on all ordnance systems in accordance with the requirements of a jointly tailored MIL-STD-1543.

3.13.3 Ordnance Electrical and Optical Circuits

3.13.3.1 Ordnance Electrical and Optical Circuit General Design Requirements

a. Ordnance system circuitry shall be shielded, filtered, grounded, or otherwise isolated to preclude energy sources such as electromagnetic energy or stray light from the Ranges and/or launch vehicle from causing undesired output of the system.

b. Category A ordnance systems shall be designed so that the initiating devices can be installed in the system just prior to final electrical and/or optical hookup on the launch pad. **NOTE**: It is understood that this requirement cannot always be met. Exceptions shall be handled on a case-by-case basis where the Range User has demonstrated compliance with the intent.

1. Initiating device locations shall be accessible to facilitate installation and removal and electrical and/or optical connections as late as possible in the launch countdown.

2. Launch complexes shall be designed to accommodate this accessibility requirement.

c. Separate power sources and/or busses are required for ordnance initiating systems.

d. RF energy shall not be used to ignite initiating devices.

e. Electrical firing circuits shall be isolated from the initiating ordnance case, electronic case, and other conducting parts of the vehicle.

1. If a circuit is grounded, there shall be only one interconnection (single ground point) with other circuits. **NOTE:** Static bleed resistors of 10 kilohms to 100 kilohms are not considered to violate the single point ground.

2. This interconnection shall be at the power source only.

3. Other ground connections with equivalent isolation shall be handled on a case-by-case basis.

f. Ungrounded circuits capable of building up static charge shall be connected to the structure by static bleed resistors of between 10 kilohms and 100 kilohms.

g. Firing circuit design shall preclude sneak circuits and unintentional electrical paths due to such faults as ground loops and failure of solid state switches.

h. Redundant circuits are required if loss of power or signal may result in injury to personnel or be a detriment to safety critical systems.

1. The elements of a redundant circuit shall not be terminated in a single connector where the loss of such connector will negate the redundant feature.

2. Redundant circuits should be separated to the maximum extent possible.

3.13.3.2 Ordnance Electrical and Optical Circuit Shielding

a. Shields shall not be used as intentional current-carrying conductors.

b. Electrical firing circuits shall be completely shielded or shielded from the initiating ordnance or LFU back to a point in the firing circuit at which filters or absorptive devices eliminate RF entry into the shielded portion of the system.

c. RF shielding shall provide a minimum of 85 percent of optical coverage ratio. (Optical coverage ratio is the percentage of the surface area of the cable core insulation covered by a shield). A solid shield rather than a mesh shield would have 100 percent coverage.

d. There shall be no gaps or discontinuities in the termination at the back faces of the connectors or apertures in any container that houses elements of the firing circuit.

e. Electrical shields terminated at a connection shall be joined around the full 360^o circumference of the shield.

f. All metallic parts of the initiating ordnance sub-system that are physically connected shall be bonded with a DC resistance of less than 2.5 milliohms.

g. Firing, control, and monitor circuits shall all be shielded from each other.

3.13.3.3 Ordnance Electrical and Optical Circuits Wiring

a. Twisted shielded pairs shall be used unless other configurations such as coaxial leads can be shown to be more effective.

b. For low voltage circuits, insulation resistance between the shield and conductor at 500 volts DC minimum shall be greater than 2 Megohms.

c. For high voltage circuits, insulation resistance between the shield and conductor at 150 percent of rated output voltage or 500 volts, whichever is greater, shall be greater than 50 Megohms.

d. Wires shall be of sufficient size to adequately handle 150 percent of the design load for continuous duty signals (100 sec or more) on the safety critical circuit.

e. Splicing of firing circuit wires or overbraid shields is prohibited.

f. The use of wire wrap to connect wire shields is prohibited.

3.13.3.4 Ordnance Electrical and Optical Connectors

a. The outer shells of electrical connectors shall be made of metal.

b. Electrical and optical connectors shall be selected to eliminate the possibility of mismating. **NOTE:** Mismating includes improper installation as well as connecting wrong connectors.

c. Electrical and optical connectors shall be of the self-locking type or lock wiring shall be used to prevent accidental or inadvertent demating.

d. The design shall ensure that the shielding connection for an electrical connector is complete before the pin connection.

e. Shields need not be carried through a connector if the connector can provide RF attenuation and electrical conductivity at least equal to that of the shield.

f. Circuit assignments and the isolation of firing pins within an electrical connector shall be so that any single short circuit occurring as a result of a bent pin shall not result in more than 10 percent of the all-fire current. **NOTE:** Unless otherwise agreed to by Range Safety, a bent pin analysis shall be performed on all electrical connectors.

g. There shall be only one wire per pin and in no case shall an electrical connector pin be used as a terminal or tie-point for multiple connections.

h. Spare pins are allowed in electrical connectors except where a broken spare pin may have an adverse effect on a firing or control circuit.

i. Source circuits shall terminate in an electrical connector with female contacts.

j. Electrical connectors relying on spring contact shall not be used on safety critical circuits.

k. Electrical connectors shall be capable of adequately handling 150 percent of the designed electrical load continuous duty signal (100 sec or more) on safety critical circuits.

l. Optical connectors and receptacles shall be provided with self-locking protective covers or caps that shall be installed except when the connector or receptacle is in use.

m. Separate cables and connectors shall be used when redundant circuits are required.

3.13.3.5 Ordnance Electrical and Optical Circuits Switches and Relays

a. Switches and relays shall be designed to function at expected operating voltage and current ranges under worst case ground environmental conditions, including maximum expected cycle life.

b. Switches and relays used for inhibits shall not be considered adequate for RF isolation and absorption unless demonstrated by analysis and test for the specific environment of use.

3.13.3.6 Ordnance Electrical and Optical Monitoring, Checkout, and Control Circuits

a. All circuits used to arm or disarm the firing circuit shall contain means to provide remote electrical indication of their armed or safe status.

1. These inhibits shall be directly monitored.

2. GSE shall be provided to electrically monitor ARM and SAFE status of the firing circuit at all processing facilities including launch complexes up to launch.

b. Monitoring, control, and checkout circuits shall be completely independent of the firing circuits and shall use a separate and non-interchangeable electrical connector.

c. Monitoring, control, and checkout circuits shall not be routed through arm or safe plugs except when approved by Range Safety.

d. The electrical continuity of one status circuit (SAFE or ARM) shall completely break prior to the time that electrical continuity is established for the other status circuit (ARM or SAFE).

e. The safety of the ordnance system shall not be affected by the external shorting of a monitor circuit or by the application of any positive or negative voltage between 0 and 35 volts DC to a monitor circuit.

f. Monitoring and checkout current in a low voltage electroexplosive system firing line shall not exceed 1/10 the no-fire current of the EED or 50 milliamperes, whichever is less.

g. Monitor circuits shall be designed so that the application of the operational voltage will not compromise the safety of the firing circuit nor cause the ordnance system to be armed.

h. Tolerances for monitor circuit outputs shall be specified for both RF and hardline and shall be submitted to Range Safety for review and approval.

i. Maximum and minimum values for monitor circuit outputs shall be specified and submitted to Range Safety for review and approval.

j. No single point failure in monitoring, checkout, or control circuitry and equipment shall compromise the safety of the firing circuit.

k. Control circuits shall be electrically isolated from the firing circuit so that a stimulus in these circuits does not induce a stimulus greater than 20 dB of the activation level in the firing circuit.

l. The monitor circuit that applies current to the EED shall be defined to limit the open circuit output voltage to 1 volt.

3.13.4 Initiator Electrical and Optical Circuits

3.13.4.1 Electrical and Optical Low Voltage Electromechanical Circuits Design Requirements

a. All solid rocket motor ignition circuits and other high hazard ordnance systems (as determined by Range Safety) using low voltage initiators shall provide an electromechanical safe and arm (S&A) device.

b. EED ordnance systems other than solid rocket motor ignition circuits and other high hazard ordnance systems shall provide two independent circuit interrupts such as ENABLE and FIRE switches in the power side of the initiator and one safe plug that interrupts both the power and return side.

c. The safe plug shall provide interruption of the circuit after the ENABLE and FIRE switches and as close to the end item ordnance as possible.

d. The final electrical connection of an EED to the firing circuit shall be as close to the EED as possible.

e. EEDs shall be protected from electrostatic hazards by the placement of resistors from line-to-line and line-to-ground (structure). **NOTE:** The placement of line-to-structure static bleed resistances is not considered to violate the single point ground requirement as long as the parallel combination of these resistors are 10 kilohms or more.

f. The system circuitry shall be designed and/or located to limit RF power at each EED (produced by Range and/or vehicle transmitter) to a level at least 20 dB below the pin-to-pin DC no-fire power of the EED. **NOTE 1**: Electromagnetic environment evaluation shall either be by analysis or electromagnetic compatibility (EMC) testing. **NOTE 2**: Computer RF power density levels for Range facilities are available from Range Safety.

3.13.4.2 High Voltage Exploding Bridgewire Circuits

a. All solid rocket motor ignition circuits for all launch vehicles and payloads using exploding bridgewire (EBW) systems shall include a manual arming and safing plug in addition to an EBW-Firing Unit (EBW-FU).

b. An EBW-FU is required on all other EBW systems. **NOTE:** A manual arming and safing plug may also be required depending on the degree of hazard as determined by Range Safety on a case-by-case basis.

3.13.4.3 Laser Initiated Ordnance Circuits

a. The optic system design shall preclude stray energy sources such as photostrobe, magnified sunlight, arc welding, xenon strobe, lightning, static electricity, and RF from causing an undesired output. **NOTE:** This requirement shall be demonstrated during development and qualification testing.

b. Laser power sources shall have a minimum of two independent and verifiable inhibits. One of these inhibits for the main laser shall be a power interrupt plug that removes all airborne and ground power to the laser firing unit (LFU).

c. High voltage laser systems used for solid rocket motor ignition circuit shall use one of the following safety devices:

1. An LFU used in conjunction with two optical barriers capable of being armed and safed and locked and unlocked remotely. A manual safe plug capable of interrupting power to the barrier control circuits shall also be provided.

2. An optical S&A

3. An ordnance S&A

d. Low voltage laser systems such as the Diode Laser used for the solid rocket motor ignition circuit shall use one of the following safety devices:

1. An optical S&A

2. An ordnance S&A

e. Specific safety device requirements for systems other than solid rocket motor ignition circuits shall be determined on a case-by-case by Range Safety based on the degree of hazard.

f. If a low energy level end-to-end test is to be performed by the Range User when LIOS is connected to the receptor ordnance, the following requirements shall be met:

1. The energy level shall be less than 1/10,000 of the no-fire level of the LID.

2. The single failure mode maximum energy level of the test system shall be less than 1/100 of no-fire level of the LID.

3. The test source shall emit a different wave length than the main firing unit laser.

4. One of the following inhibit options shall be implemented during a low energy level test:

(a) An ordnance S&A device and a safe plug that interrupts power to the main laser shall be provided.

(b) Three independent verifiable inhibits

shall be in place to preclude inadvertent initiation of the LID by the main firing unit laser during the low level energy test. **NOTE:** One of these inhibits shall be a safe plug that interrupts power to the main laser.

(c) The explosive train shall be disconnected anywhere between the LID and the receptor ordnance.

g. If a main laser subsystem firing test is performed by the Range User when LIOS is connected to the receptor ordnance, a minimum of three independent, verifiable inhibits shall be in place.

1. Two of the inhibits shall be optical barriers capable of being independently locked in place.

2. The third inhibit shall be a safe plug that interrupts the power control circuits to the optical barriers.

h. Lasers shall be completely enclosed during checkout or provided with GSE that can enclose the laser emission path at all times the system is powered.

3.13.5 Ordnance Safety Devices

3.13.5.1 Ordnance Safety Device General Design Requirements

a. Ordnance safety devices are electrical, electromechanical, optoelectronic, optical, or mechanical devices used in all ordnance subsystems to provide isolation between the power source to firing circuits and firing circuits to initiating devices or receptor ordnance. Examples include S&A devices, Arm/Disarm devices, relays, switches, EBW-FUs, Laser Firing Units (LFUs) and manual arming/safing plugs.

b. Electrical and electronic safety devices shall remain or transfer back to their safe state in the event of input power loss.

c. All safety devices shall be capable of being functionally tested by ground test equipment.

d. Manual safety devices on the launch vehicle and payload shall be accessible up to launch. Remotely activated safety devices shall remain operable up to launch and after launch abort. **NOTE:** It is understood that this requirement cannot always be met. Exceptions shall be handled on a case-by-case basis where the Range User has demonstrated compliance with the intent.

e. The arrangement of safety devices shall maximize safety by placing the most positive and reliable form of interruption closest to the initiating device; for example, a safe plug would be located downstream of a solid state switch.

f. Ordnance and optical mechanical barriers used for safety devices shall demonstrate a reliability of 0.999 at the 95 percent confidence level to prevent initiation of the receptor ordnance or the laser initiated device LID for LIOS. **NOTE**: The test method shall be a Bruceton procedure or other statistical testing method acceptable to Range Safety.

g. Safety devices shall not require adjustment throughout their service life.

h. Each safety device shall be designed for a service life of at least 10 years after passing the acceptance test.

3.13.5.2 Ordnance Arming and Safing Plugs

a. Safing plugs shall be designed to be manually installed to provide electrical isolation of the input power from the EBW-FU or LFU.

b. Arming plugs shall be designed to be manually installed to provide electrical continuity from the input power to the EBW-FU or LFU.

c. The design of the arming and safing plugs and their location shall ensure easy access for plug installation and removal during assembly and checkout in all prelaunch processing facilities, including the launch complexes.

d. Arming and safing plugs shall be designed to be positively identifiable by color, shape, and name.

e. The design of arming and safing plugs and their location shall ensure easy access for plug installation and removal just prior to final launch complex clear. **NOTE:** It is understood that this requirement cannot always be met. Exceptions shall be handled on a case-by-case basis where the Range User has demonstrated compliance with the intent.

f. For low voltage systems (EED) that use a safing plug instead of an electromechanical S&A, the safing plug shall be designed to electrically isolate and short the initiator side of the firing circuit. **NOTE:** Isolation shall be a minimum of 10 kilohms.

3.13.5.3 Low Voltage EED Electromechanical S&As

a. Electromechanical S&As shall provide mechanical isolation of the EED from the explosive train and electrical isolation of the firing circuit from the EEDs.

b. When the S&A is in the SAFE position, the power and return lines of the firing circuit shall be disconnected. The bridgewire shall be shorted and grounded through a 10 kilohm to 100 kilohm resistor and the explosive train shall be interrupted by a mechanical barrier capable of containing the EED output energy without initiating the explosive.

c. Transition from the SAFE to ARM position shall require 90° of rotation of the mechanical barrier for rotating S&As containing ordnance in the barrier. **NOTE:** SAFE to ARM transition tolerances for other electromechanical S&A devices require specific Range Safety approval.

d. The S&A device shall not be capable of propagating the detonation with the barrier rotated at least 50° from SAFE for a 90° rotational barrier. **NOTE**: This position shall be 50 percent of the travel distance between ARM and SAFE for sliding barriers.

e. The mechanical lock within the S&A shall prevent inadvertent transfer from the ARM to SAFE position (or vice versa) under all ground operational environments without the application of any electrical signal.

f. S&A design shall incorporate provisions to safe the ordnance train from any rotor and/or barrier position.

g. S&As shall be capable of being remotely safed and armed. They shall not be capable of being manually armed, but shall be capable of being manually safed.

h. Remote and manual safing shall be accomplished without passing through the ARM position.

i. The S&A SAFE signal shall not be indicated visually or remotely unless the device is less than 10° from the SAFE position for rotating systems or 10 percent from the SAFE position for sliding barriers.

j. No visual indication of SAFE or ARM shall appear if the device is in between the SAFE and ARM positions. **NOTE:** The S&A will be considered “not safe” or ARMED if the indicator does not show SAFE.

k. The electrical continuity of one status circuit of the S&A device (SAFE or ARM) shall completely break prior to the time that the electrical continuity is established for the other status circuit (ARM or SAFE).

l. A remote status indicator shall be provided to show the armed or safed condition.

1. The device shall also indicate its ARM or SAFE status by visual inspection.

2. There shall be easy access to this visual indication throughout ground processing.

m. S&A device locations on the vehicle shall be accessible to facilitate installation and removal and electrical and ordnance connections during final vehicle closeout.

n. A safety pin shall be used in the S&A to prevent movement from the SAFE to the ARM position when the arming signal is applied.

1. Rotation and/or transition of the mechanical barrier to align the explosive train and electrical continuity of the firing circuit to the EEDs shall not be possible with the safety pin installed.

2. Removal of the safety pin shall not be possible if the arming circuit is energized.

3. The retention mechanism shall be capable of withstanding an applied force of at least 100 lb tension or a torque of at least 100 in. lb without failure.

4. Removal of the safety pin shall not cause the S&A to automatically arm.

5. Removal of the safety pin shall be inhibited by a locking mechanism requiring 90^o rotation of the pin. **NOTE:** The removal force shall be 3 to 10 in. lb of torque.

6. When inserted, the pin shall manually safe the device.

7. The safing pin shall be accessible through final launch complex clear.

8. The force required for safing pin insertion shall be between 20 and 40 lb and/or 20 to 40 in. lb of torque.

9. The safing pin shall provide a means of attaching warning streamers.

10. When installed, each safing pin shall be marked by a red streamer.

o. All S&A devices shall be designed to withstand repeated cycling from ARM to SAFE for at least 1000 cycles, or at least five times the expected number of cycles, whichever is greater, without any malfunction, failure, or deterioration in performance.

p. A constant 1 hr application of S&A arming voltage with the safing pin installed shall not cause the explosive in the unit to function or degrade to a point that it will no longer function if such a failure could create a hazard.

q. The time required to arm or safe an S&A device shall not exceed 1 sec after application of the actuation signal.

r. The S&A shall not initiate and shall be safe to handle for subsequent disposal after being subjected to a 20-ft drop on to a steel plate.

s. The S&A shall have shielding caps attached on the firing connectors during storage, handling, transportation, and installation up to firing line connection.

t. The shielding cap shall have a solid metal outer shell that makes electrical contact with the firing circuit case in the same manner as the mating connector.

3.13.5.4 Mechanical S&As

a. Electrically actuated S&As shall be used unless justification for mechanical S&As is provided to and approved by Range Safety.

b. Range Safety approved mechanical S&As shall incorporate the same features as electrically actuated devices except that arming and safing is performed mechanically. **NOTE:** Normally, these devices are armed by a liftoff lanyard or by stage separation.

c. These S&As shall be designed to withstand repeated cycling from the ARM to the SAFE position for at least 300 cycles without malfunction, failure, or deterioration in performance.

3.13.5.5 EBW Firing Units

a. The EBW-FU shall provide circuits for capacitor charging, bleeding, charge interruption, and triggering.

b. The charged capacitor circuit shall have a dual bleed system with either system capable of independently bleeding off the stored capacitor charge.

c. EBW-FU design shall provide a positive remotely controlled means of interrupting the capacitor charging circuit.

d. A gap tube shall be provided that interrupts the EBW trigger circuit.

e. EBW-FUs shall be designed to be discriminatory to spurious signals in accordance with MIL-STD-461.

f. At a minimum, EBW-FU monitor circuits shall provide the status of the trigger capacitor, high voltage capacitor, arm input, inhibit input (if used), and power.

g. The insulation resistance between each EBW-FU high voltage output circuit and the case shall be designed to be not less than 50 Megohms at 500 Vdc.

h. The isolation resistance between EBW-FU output circuits and any other circuits shall be not less than 50 megohms.

i. Remote discharged indicators for EBW-FUs shall not appear unless the capacitor bank voltage is one-half or less of the no-fire voltage of the EBW. The EBW-FU shall be considered not safe if the indicator does not show DISCHARGED.

j. The EBW-FU shall be capable of being remotely safed and armed.

3.13.5.6 Laser Firing Units, Optical Barriers, Optical S&As, and Ordnance S&As

a. The following laser firing unit, optical barrier, optical S&A, and ordnance S&A design requirements shall be applied according to the device used.

b. The conceptual configuration of the devices to be used and their planned prelaunch testing shall be coordinated with Range Safety as early as possible to ensure the configuration is acceptable.

3.13.5.6.1 Laser Firing Units.

a. LFU General Design Requirements.

1. LFUs shall provide a positive, remotely controlled means of interrupting the power to the firing circuit.

2. Capacitor charging circuits shall have a dual bleed system with each system capable of independently bleeding off the stored charge.

3. A gap tube shall be provided that interrupts the trigger circuit in a high voltage LFU.

4. LFUs shall be designed to be discriminatory to spurious signals in accordance with MIL-STD-461.

5. Low voltage LFUs shall provide a continuous spurious energy monitor and/or detection circuit on the input firing line capable of indicating when 1/10 of the minimum input firing voltage or current firing is exceeded.

b. LFU Monitor Circuits.

1. At a minimum, LFU monitor circuits shall provide the status of the trigger capacitor, high volt-age capacitor, arm input, barrier position, barrier locked/unlocked, inhibit input, and power as applicable.

2. The electrical continuity of one status circuit shall completely break prior to the time that the electrical continuity is established for the other status circuit.

c. LFU CHARGED and DISCHARGED Indicators. A remote DISCHARGED indicator for LFUs that use a capacitor bank shall not appear unless the capacitor bank voltage is 50 percent or less of the no-fire voltage of the LID. **NOTE:** The LFU shall be considered “not safe” if the indicator does not show DISCHARGED.

3.13.5.6.2 Optical Barriers.

a. Optical Barrier General Design Requirements.

1. The SAFE position of the optical barrier shall be capable of absorbing or redirecting the complete optical energy source to a safe receiver.

(a) The barrier shall be capable of absorbing and/or redirecting 100 times the maximum energy that the laser can generate.

(b) Depending on barrier design, the safety factor shall be calculated using several possible variables such as distance from nominal beam spot to the edge of the barrier or the edge of the aperture, distance and/or degrees between ARM and SAFE, laser energy deflected, and mechanical tolerances.

2. The optical barrier shall maintain the safety margin and function nominally after being pulsed by the main laser a minimum of four times the expected lifetime number of pulses or 10 pulses, whichever is greater, at the maximum firing rate and power of the laser.

3. The control of barriers, mechanical locks, and monitors shall be independent of the firing circuit.

4. A constant 5-min application of arming voltage with the mechanical lock of the barriers engaged shall not cause the optical train to go to the ARM position.

5. All optical barriers shall be designed to withstand repeated cycling from the ARM to the SAFE positions for at least 1,000 cycles without any malfunction, failure, or deterioration in performance. **NOTE:** If the device is to be used for a program with a known operating life cycle, Range Safety may accept a design cycle life of at least five times the expected number of cycles.

b. Optical Barrier Status Indicators.

1. A remote status indicator for the optical barriers located in LFU or optical S&A shall be provided.

2. A visual status indicator of optical barrier status shall also be provided on the device or at a nearby location so that it is easily seen by operating personnel.

(a) If a visual status indicator is provided on the barrier, it shall be readily accessible to personnel on the complex and/or facility.

(b) The design solution for a visual indicator shall not result in an external light source path for hazardous light energy to enter the LIOS system.

(c) If a visual status indicator on the LFU or S&A device is not provided, redundant elec-

tronic remote status indicators shall be provided at the launch pad and launch control center to show the armed or safe status of the LFU or S&A barriers.

3. The SAFE signal shall only be indicated when the optical barriers are in a position that will not align the optical train and not allow initiation of the LID with a reliability of 0.999 at the 95 percent confidence level.

4. Bruceton-type testing or other statistical methods acceptable to Range Safety shall be performed to establish reliability.

5. The optical barrier will be considered "not safe" or armed if the indicator does not show SAFE.

3.13.5.6.3 Optical S&As.

a. When an optical S&A device is in the laser SAFE position, the following criteria shall be met:

1. The optical transfer assembly shall be interrupted by a minimum of two mechanical barriers that can be mechanically locked in place.

2. The main laser power circuit shall be electrically disconnected. **NOTE:** This main laser power interrupt capability is not required if the power circuit to the mechanical barriers is interrupted by an arm and/or safe plug.

3. Optical S&As shall be capable of being remotely safed and armed.

4. Optical S&As shall not be capable of being manually armed but they shall be capable of being manually safed.

5. Remote and manual safing shall be accomplished without passing through the armed position.

b. Optical S&A barriers shall meet the requirements of the **Optical Barriers** section of this Chapter.

c. The electrical continuity of one status circuit shall completely break prior to the time that the electrical continuity is established for the other status circuit.

d. The S&A shall provide status of the optical barriers (ARM, SAFE), barriers locked/ unlocked, and electrical inhibits.

e. The insulation resistance between each S&A circuit and the case shall not be less than 2 megohms at 500 Vdc.

f. All S&A devices shall be designed to withstand repeated cycling from ARM to SAFE for at least 1000 cycles or at least five times the expected number of cycles, whichever is greater, without any malfunction, failure, or deterioration in performance.

g. A constant 5 min application of S&A arming voltage shall not cause malfunction, failure, or deterioration in performance.

h. The time required to ARM or SAFE an S&A device shall not exceed 1 sec after application of the actuation signal.

3.13.5.6.4 Ordnance S&As.

a. Ordnance S&A General Design Requirements.

1. Ordnance S&As shall provide mechanical isolation of the explosive train.

2. When the device is in the SAFE position, the explosive train shall be interrupted by a mechanical barrier capable of containing the explosive.

3. SAFE to ARM Transition

(a) Transition from the SAFE to ARM position shall require 90^{o} of rotation of the mechanical barrier for rotating S&As containing ordnance in the barrier.

(b) SAFE to ARM transition tolerances for other electromechanical S&A devices shall be approved by Range Safety.

4. Detonation Propagation

(a) The device shall not be capable of propagating the detonation with the barrier rotated less than 50^{o} from SAFE for a 90^{o} rotational barrier.

(b) The device shall not be capable of propagating the detonation with the barrier at 50 percent of the travel distance between ARM and SAFE for sliding barriers.

5. Ordnance S&A device locations on the vehicle shall be accessible to facilitate installation and/or removal of ordnance connections during final vehicle closeout.

6. The S&A shall not initiate and shall be safe to handle for subsequent disposal after being subjected to a 20-ft drop on to a steel plate.

b. Ordnance S&A ARM and SAFE Mechanisms

1. The S&A device shall be designed to incorporate provisions to safe the ordnance train from any rotor or barrier position.

2. The time required to ARM or SAFE an S&A device shall not exceed 1 sec after application of the actuation signal.

3. All S&A devices shall be designed to withstand repeated cycling from ARM to SAFE for at least 1,000 cycles or at least five times the expected number of cycles, whichever is greater, without any malfunction, failure, or deterioration in performance.

4. A mechanical lock in the S&A shall prevent inadvertent transfer from the ARM to SAFE position or the SAFE to ARM position under all operating environments without the application of any electrical signal.

5. S&As shall be capable of being remotely safed and armed.

6. Ordnance S&As shall not be capable of being manually armed but they shall be capable of being manually safed.

7. Remote and manual safing shall be accomplished without passing through the armed position.

c. *Ordnance S&A Status Indicators*

1. The electrical continuity of one status circuit of the S&A device (SAFE or ARM) shall completely break prior to the time that the electrical continuity is established for the other status circuit (ARM or SAFE).

2. Ordnance S&A Remote and Visual Status Indicators:

(a) A remote status indicator shall be provided to show the armed or safed condition.

(b) A visual status indicator shall be provided to show the armed or safed condition by simple visual inspection.

(c) Easy access to the visual status indicator shall be provided throughout ground processing.

3. The S&A SAFE signal shall not be indicated visually or remotely unless the device is less than 10^{o} from the SAFE position for rotating systems or 10 percent from the SAFE position for sliding barriers.

4. No visual indication of SAFE or ARM shall appear if the device is in between SAFE and ARM positions. **NOTE:** The S&A will be considered “not safe” or armed if the indicator does not show SAFE.

d. *Ordnance S&A Safing Pins*

1. A safing pin shall be used in the S&A device to prevent movement from the SAFE to the ARM position when an arming signal is applied.

2. Rotation and/or transition of the mechanical barrier to the aligned explosive train shall not be possible with the safing pin installed.

3. When inserted and rotated, the safing pin shall manually safe the device.

4. The safing pin shall be accessible through final launch complex clear.

5. Removal of the safing pin shall not be possible if the arming circuit is energized.

6. The retention mechanism of the safing mechanism shall be capable of withstanding an applied force of at least 100 lb tension or a torque of at least 100 in. lb without failure.

7. Removal of the safing pin shall not cause the device to automatically arm.

8. Removal of the safing pin shall be inhibited by a locking mechanism requiring 90^{o} rotation of the pin. The removal force shall be 3 to 10 in. lb of torque.

9. The force required for safing pin insertion shall be between 20 and 40 lb and/or 20 to 40 in. lb of torque.

10. A constant 1 h application of S&A arming voltage, with the safing pin installed, shall not cause the explosive in the unit to function.

3.13.6 Ordnance Initiating Devices

3.13.6.1 Ordnance Initiating Device General Design Requirements

a. The explosive or pyrotechnic mix shall not degrade, decompose, or change chemically over its life causing a more sensitive device.

b. Periodic testing of ordnance to verify that no sensitivity changes have occurred shall be in accordance with DoD-E-83578, unless it can be shown that sensitivity with aging is not a credible concern with the specific explosive composition.

c. Ordnance should be designed for a service life of at least 10 years, with a design goal of 15 years.

d. The decomposition, cook-off, and melting temperatures of all explosives shall be at least 30^{o}C higher than the maximum predicted environmental temperature to which the material will be exposed during storage, handling, transportation, and launch.

3.13.6.2 Low Voltage EEDs

a. One amp/one watt no-fire survivability of low voltage EEDs is required, as determined from the 0.1 percent firing level of the EED with 95 percent confidence using the Bruceton test or other statistical testing methods acceptable to Range Safety.

b. EEDs shall be designed to withstand a constant direct current firing pulse of 1 ampere and 1 watt power for a period of 5 min duration without initiation or deterioration of performance.

c. The EED main body shall not rupture or fragment when the device is fired. **NOTE:** Displacement or deformation of the connector and main housing is permissible; rupture or deformation of the outer end is permissible.

d. The autoignition temperature shall not be less than 150^{o}C.

e. Carbon bridgewires and conductive mixes without bridgewires are prohibited.

f. EEDs shall not fire or deteriorate in performance (if failure can create a hazard) as a result of being subjected to an electrostatic discharge of 25 kV from a 500 picofarad capacitor applied in the pin-to-case mode without a series resistor, and in the pin-to-pin mode with a 5 kilohms resistor in series.

g. The EED shall not initiate and will perform to specification (if failure can create a hazard) after being subjected to a 6-ft drop on to a steel plate.

h. The EED shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-ft drop on to a steel plate.

i. Insulation resistance between pin-to-case shall not be less than 2 megohms at 500 Vdc.

j. The outer case of the EED main body shall be made of conductive material, preferably metal.

k. RF survivability shall meet the testing criteria described in MIL-STD-1576.

l. Shielding caps shall be provided and placed on the EED during shipment, storage, handling, and installation up to the point of electrical connection.

1. The shielding cap shall have an outer shell made of conductive material that provides an RF shield and makes electrical contact with the EED case.

2. There shall be no RF gaps around the full 360^{o} mating surface between the shielding cap and EED case.

3. The shielding cap shall be designed to accommodate the torquing tool during installation.

4. Shorting plugs (caps) shall not be used as a substitute for shielding caps.

3.13.6.3 High Voltage Exploding Bridgewires

a. Explosive materials shall be a secondary explosive such as Pentaerythritoltetranitrate (PETN) or Cyclotrymethylenetrinitramine (RDX).

b. Insulation resistance pin-to-case shall be designed to be not less than 50 megohms at 500 Vdc.

c. A voltage blocking gap shall be provided.

1. The gap breakdown voltage shall not be less than 650 Vdc when discharged from a 0.025 $\pm$10 percent microfarad capacitor.

2. The nominal gap breakdown voltage tolerance shall be specified and approved by Range Safety.

d. The EBW shall not fire or deteriorate in performance (if failure can create a hazard) upon being subjected to a voltage of 125 to 130 Volts root mean square (Vrms) at 60 Hz applied across the terminals or between the terminals and the EBW body for 5 min $\pm$10 sec.

e. The EBW shall not fire or degrade to the extent that it is unsafe to handle when 230 $\pm$10 Vrms at 60 Hz is applied across the terminals or between the terminals and EBW body for 5 min $\pm$10 sec.

f. The EBW shall not fire or deteriorate in performance (if failure can create a hazard) upon being subjected to a source of 500 $\pm$25 Vdc having an output capacitance of 1.0 $\pm$10 percent microfarads applied across the terminals or between the terminals and the EBW body for 60 to 90 sec.

g. The EBW shall not fire or deteriorate in performance (if failure can create a hazard) after exposure to that level of power equivalent to absorption by the test item of 1.0 watt average power at any frequency within each RF energy range, as specified in Table 3-4. The frequency shall be applied across the input terminals of the EBW detonator for 5.0 to 6.0 sec.

Table 3-4
RF SENSITIVITY

Frequency (in Mhz)	Type
5 - 100	Continuous Wave
250 - 300	Continuous Wave
400 - 500	Continuous Wave
800 - 1000	Continuous Wave
2000 - 2400	Continuous Wave
2900 - 3100	Continuous Wave
5000 - 6000	Continuous Wave
9800 - 10000	Continuous Wave
16000 - 23000	Pulse Wave [a]
32000 - 40000	Pulse Wave [a]

[a] Pulsed repetition frequency shall be not less than 100 Hz and the pulse width shall be a minimum of 1.0 microsec.

h. The EBW shall not fire or deteriorate in performance (if failure can create a hazard) as a result of being subjected to an electrostatic discharge of

25 kV from a 500 picofarad capacitor applied in the pin-to-case mode without a series resistor and in the pin-to-pin mode with a 5 kilohm resistor in series.

i. The autoignition temperature of the EBW shall not be less than 150^{o}C.

j. The EBW shall not initiate and shall perform to specification (if failure can create a hazard) after being subjected to a 6-ft drop on to a steel plate.

k. The EBW shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-ft drop on to a steel plate.

3.13.6.4 Laser Initiated Devices

a. Laser initiated devices (LIDs) shall have specific energy density, spot size, pulse width, and wave length characteristics with a specified tolerance level for each characteristic.

b. LIDs shall not use primary explosives.

1. If modified secondary (composition) explosives are used, their sensitivity characteristics shall be established by test in accordance with MIL-STD-1751, ADA 086259, or the equivalent.

2. The test requirements and test report shall be reviewed and approved by Range Safety.

c. Flight configuration LIDs shall be tested to determine their susceptibility to all stray energy sources such as strobe, sunlight, arc welder, flash-lamps, lightning, RF, AC, and DC electrical energy present during prelaunch processing up to the launch environment. **NOTE:** This susceptibility applies to both inadvertent firing and dudding if dudding can create a hazard.

1. At a minimum, the sensitivity characteristics to these energy sources will be established by functioning a minimum of 45 LIDs per the Bruceton test or other statistical testing method acceptable to Range Safety in terms of spot size, pulse width, energy density, and wave length.

2. A correlation between the above test and the no-fire level established for the LID shall be provided to Range Safety for review and approval. At a minimum, the LID no-fire energy shall be 10^4 greater than any credible stray energy source.

3. If the above LID sensitivity requirements are not met, the explosive train (LID to explosive transfer assembly [ETA] or ETA to receptor ordnance interface) shall remain disconnected until just prior to final pad evacuation for launch, or an ordnance S&A device shall be provided between the LID and the ETA.

d. No-fire level survivability is required as determined from the 0.1 percent firing level of the LID with 95 percent confidence using the Bruceton test or other statistical methods acceptable to Range Safety.

1. The test shall take into account the effects of the temperature of the explosive as well as effects caused by manufacturing variations in explosive grain size and pressure.

2. The no-fire level shall be applied for a minimum of 5 min without firing or dudding the LID if dudding can create a hazard.

e. The minimum all-fire level shall be at least 10 times the no-fire level.

f. LIDs shall not be exposed to energy density levels greater than 1/10,000 the no-fire level of the ordnance initiator during prelaunch processing, shipment, storage, handling, installation, and testing. **NOTE:** This energy constraint is to be applied at the end of the fiber optic cable just prior to the cable entering the laser ordnance initiator reflective coating.

g. LIDs shall dissipate heat faster than single failure conditions can input into the device without initiating or dudding (if dudding can create a hazard). **NOTE 1**: An analysis shall be provided to demonstrate compliance with this requirement. **NOTE 2**: This does not include full laser firing energy output.

h. Optical shielding and protective caps shall be provided for LIDs during prelaunch processing, including shipment, storage, handling, installation, and testing.

1. Shielding and protective cap devices shall prevent exposure of the LID to energy density levels greater than 1/10,000 of the no-fire level of the LID.

2. Reflective coatings of the LID shall not be considered part of the shield.

i. The shielding cap shall be designed to accommodate the tool used during installation without the removal of the cap.

j. Autoignition temperature of the LID shall not be less than 150^{o}C.

k. LIDs shall not initiate and shall perform to specification (if failure can create a hazard) after being subjected to a 6-ft drop test on to a steel plate.

l. The LID shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-ft drop test on to a steel plate.

m. LIDs shall not fire or deteriorate in performance (if failure can create a hazard) as result of being subjected to an electrostatic discharge of 25 kV from a 500 picofarad capacitor. **NOTE**: The test configuration shall be approved by Range Safety.

3.13.6.5 Percussion Activated Devices

a. Stab initiation of percussion activated devices (PADs) is prohibited.

b. Each initiator shall have a positive safety interrupter feature that can be mechanically locked in place.

c. The initiator and its interrupter shall be designed to withstand all transportation, handling, and installation environments.

d. The interrupter safety lock shall be designed to remain in place during and after installation.

e. The interrupter safety lock shall be designed to be removed after installation.

f. The design shall ensure the PAD cannot be assembled without the interrupter.

g. Percussion initiators shall be designed so that the operating energy is at least twice the all-fire energy.

h. Percussion initiator no-fire energy shall be such that the percussion initiator shall not fire when subjected to an energy of 50 percent of the all-fire energy.

3.13.6.6 Non-Explosive Initiators

Non-explosive initiators (NEIs) shall be handled on a case-by-case basis to ensure safety of the system design and shall be classified as either Category A or B.

3.13.7 Receptor Ordnance

Explosive transfer systems (ETS) are used to transmit the initiation reaction from the initiator to the receptor ordnance. Most ETS harnesses contain flexible confined detonation cord (FCDC), mild detonating cord (MDC), or mild detonating fuse (MDF) terminated by end booster caps or manifolds. ETSs shall be designed to meet the applicable safety sections of DoD-E-83578 and this section.

a. The explosive or pyrotechnic mix shall not degrade, decompose, or change chemically over its life causing a more sensitive device.

b. Periodic testing of ordnance to verify no sensitivity changes shall be in accordance with DoD-E-83578 unless it can be shown that the sensitivity with aging is not a credible concern with the specific explosive composition.

c. Explosives used in ETS lines shall be secondary explosives.

d. FCDC shall not fragment or separate from end fittings upon initiation. **NOTE:** Gaseous emission is permissible.

e. The ETS shall not detonate and shall be capable of performing its function (if failure can create a hazard) after being subjected to a 6-ft drop on to a steel plate.

f. The ETS shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-ft drop on to a steel plate.

g. All ETS interconnections shall provide for safety (lock) wiring or a Range Safety approved equivalent.

h. An electrically conductive path shall exist between ETS components and their attachment fittings. The bonding resistance should be designed to be 2.5 milliohms but in no case shall the resistance exceed 5 ohms.

i. ETS fittings shall be designed and located to facilitate installation of the end receptor ordnance components in the launch vehicle as late as practical.

j. Fittings that should not be reversed or interchanged (because they may cause a hazard) shall be designed so that reverse installation or interchange is not possible.

k. Exposed end fittings shall be equipped with protective caps.

l. Receptor ordnance shall be designed to meet the applicable safety sections of DoD-E-83578 and this section and shall use secondary high explosives such as PETN, RDX, Cyclotetramethylenetetranitramine (HMX), or 2,2,4,4,6,6 Hexanifrostilbene (HNS).

1. Explosives shall be non-hygroscopic.

2. Specific approval from Range Safety is required for all explosive compositions.

m. The receptor ordnance shall not detonate after being subjected to a 6-ft drop test on to a steel plate.

n. The receptor ordnance shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-ft drop onto a steel plate.

3.13.8 Ordnance Test Equipment

3.13.8.1 Ordnance Test Equipment General Design Requirements

a. All test equipment shall be designed to meet standard industry safety requirements such as those established by ANSI, OSHA, and NFPA.

b. All ordnance test equipment such as continuity and bridgewire resistance measurement devices shall be inspected and tested for voltage and optical isolation and limitation. **NOTE:** These tests can be accomplished at the Range Calibration Laboratory.

1. These devices shall be designed so that they will not pass greater than 1/10 of the no-fire energy across an EED bridgewire.

2. These devices shall be analyzed to verify that rough handling, dropping, or single component failure will not result in negating the current-limiting feature.

3. Clear cases of unacceptable energy or current for a particular resistance range or ranges shall be excluded from use by disablement by the manufacturer or local authority before certification.

4. Certification of each device shall include a tabular listing (to be kept with or marked on each meter) of the energy level and current levels available at each of the selectable ranges for the meter.

c. The test results shall be submitted to Range Safety for approval prior to equipment use on the Ranges.

3.13.8.2 Stray Current Monitors

a. A stray current monitor shall be provided for all low voltage (EED) solid rocket motor ignition circuits and other high hazard ordnance systems as determined by Range Safety.

b. The stray current monitor shall be installed and remain connected until the electrical connection of the actual initiators is accomplished. **NOTE:** The monitor will be installed at a time during vehicle processing mutually agreeable to Range Safety and the Range User.

c. The stray current monitor shall provide a stray current device such as a fuse or automatic recording system capable of detecting 1/10 of the maximum safe no-fire current.

d. The monitoring device shall be installed in the firing line.

3.13.8.3 Ground Support Test Equipment

The design of test equipment used to test ground support equipment shall be reviewed and approved by Range Safety.

3.13.8.4 Laser Test Equipment

a. All laser test equipment that has the capability to directly or indirectly fire the LID shall be assessed and approved by Range Safety.

b. Laser test equipment shall meet the following design criteria:

1. The energy level shall be less than 1/10,000 of the no-fire level of the LID.

2. The single failure mode energy level of the test equipment shall be less than 1/100 of the no-fire level of the LID.

3. The test source shall emit a different wave length from that of the firing unit laser.

3.13.9 Ordnance Data Requirements

The following ordnance data requirements shall be incorporated in the MSPSP: (See Appendix 3A for guidance.)

3.13.9.1 Ordnance General Design Data

a. Data to verify compliance with the design and test requirements of the **Ordnance Systems** section of this Chapter shall be submitted to Range Safety for review and approval prior to the arrival of ordnance at the Ranges.

b. All schematics and functional diagrams shall have well defined, standard Institute of Electrical and Electronics Engineers (IEEE) or military specification terminology and symbols.

3.13.9.2 Ordnance Hazard Classifications and Categories

a. DoD/UN hazard classifications (class, division, and compatibility group) in accordance with DoD 6055.9-STD.

b. DOT classification

c. The Range Safety ordnance device and system hazard category for each ordnance item and system.

d. Test results and/or analysis used to classify the ordnance devices and systems as Category A or B

3.13.9.3 Ordnance System Design Data

a. A block diagram of the entire ordnance system

b. A complete line schematic of the entire ordnance system from the power source to the receptor ordnance, including telemetry pick-off points and ground (umbilical) interfaces

c. Diagrams showing the location of all ordnance components on the vehicle

d. A description of wiring, ETS, and Fiber Optic Cable (FOC) routing

e. A description of electrical, ETS, and optical connections and connectors

f. Detailed, complete schematics of the entire ordnance system showing component values such as resistance and capacitance, tolerances, shields, grounds, connectors, and pin outs. **NOTE 1:** The schematics shall include all other vehicle components and elements that interface or share common usage with the ordnance system. **NOTE 2:** All pin assignments shall be accounted for.

g. Detailed narrative description of the operation of the ordnance system, including all possible scenarios

h. FMECA for each ordnance system

i. A summary list of all noncompliances, both meets intent and waiver

j. An operational flow of the ordnance system processing and checkout, including time lines and summaries of each procedure to be used

k. A sketch showing the accessibility of manual arming and safing devices

l. Specification drawings and documents for all airborne and ground ordnance systems

3.13.9.4 Ordnance Component Design Data

a. A complete and detailed description of each ordnance system component and how it functions

b. Specification drawings and documents for all airborne and ground ordnance components

c. Illustrated breakdown of all mechanically operated ordnance components

d. Part number, manufacturer, and net explosive weight for each ordnance item

e. Temperature and humidity requirements for each ordnance item

f. Bridgewire resistance, maximum safe-no-fire current, and minimum all-fire current for each low voltage EED

g. Maximum no-fire voltage and minimum all-fire voltage for each EBW

h. Maximum no-fire energy and minimum all-fire energy for each LID and PAD

3.13.9.5 Ordnance Ground Systems Design Data

a. A complete description of the ground test equipment that will be used in the checkout of ordnance devices and systems, including general specifications and schematics for all test equipment

b. Specifications, schematics, and a complete functional description of the low voltage stray current monitor

c. Schematics of all ordnance system monitor circuits from the ordnance component pick-off points to the OSC termination

d. Calibration data for all monitor circuit terminations that will be provided to the OSC

e. A complete and detailed description of the airborne and ground ordnance telemetry system and how it functions, including general specifications and schematics

f. The following information is required for ordnance continuity and bridgewire resistance measurement devices:

1. Maximum safe no-fire energy of the ordnance being tested

2. A declaration of any certification currently in effect for the instrument along with the manufacturer's specifications including:

(a) Range
(b) Accuracy
(c) Power supply and recharge capability
(d) Self-test features
(e) Schematics

3. Failure analysis including the outcome of the energy analysis (open circuit or maximum terminal voltage) and current limit analysis (short circuit or maximum output current)

4. Instrument description including any modifications required for operational use and details of safety design features such as interlocks

5. Description of intended operations

3.14 ELECTRICAL AND ELECTRONIC EQUIPMENT

3.14.1 Electrical and Electronic Ground Support Equipment and Flight Hardware General Design Require-ments

3.14.1.1 Electrical and Electronic Ground Support Equipment and Flight Hardware Power Cut Off

All electrical and electronic ground support equipment (EGSE) and flight hardware shall have a means to cut off power prior to installing, replacing, or interchanging units, assemblies, or portions thereof.

3.14.1.2 EGSE and Flight Hardware Power Transient

Safety critical systems shall be protected against power transients from facility power.

3.14.1.3 EGSE and Flight Hardware Connectors

a. If a hazardous condition can be created by mismating or reverse polarity, connectors shall have alignment pins, keyway arrangements, or other means to make it impossible to incorrectly mate. **NOTE:** Mismating includes improper installation as well as connecting wrong connectors.

b. Color coding may be used in addition to, but not in lieu of, the more positive means of mismate prevention.

c. If a hazardous event can occur, the following precautions shall be taken:

1. Power and signal leads shall not be terminated on adjacent pins of a connector.

2. Wiring shall be isolated so that a single short circuit occurring in a connector cannot affect other components.

3. Pin locations shall be assigned to prevent inadvertent pin-to-pin and pin-to-case shorts.

4. Spare pins should not be used in connectors controlling hazardous operations or safety critical functions.

d. Connectors used in safety critical or hazardous systems shall be of the locking type.

e. Connectors relying on spring contact shall not be used in safety critical or hazardous systems.

f. Where possible, plug and socket type connectors shall be used in safety critical or hazardous systems.

g. A bent pin analysis shall be performed on all safety critical or hazardous system connectors that cannot be verified as a good mate after final connection.

3.14.1.4 EGSE and Flight Hardware Grounding, Bonding, and Shielding

a. Equipment shall be designed and constructed to ensure that all external parts, shields and surfaces, exclusive of radiating antennas and transmission line terminals, are at ground potential.

b. Shields shall not be used as current carrying ground connections, except for coaxial cables.

c. Circuits that operate safety critical or hazardous functions shall be protected from the electromagnetic environment to preclude inadvertent operation.

3.14.1.5 EGSE and Flight Hardware Cables

a. Cables shall be supported and protected against abrasion or crimping.

b. Cables shall be located or protected so as not to present a tripping hazard.

c. Cables in hazardous areas shall be designed so that they do not, in and of themselves, create a hazard.

d. Cables shall be selected according to the following criteria:

1. Toxicity
2. Combustibility and smoke production
3. Offgassing
4. Compatibility with liquids in the area
5. Environmental exposure

3.14.1.6 EGSE and Flight Hardware Batteries

3.14.1.6.1 EGSE and Fight Hardware Battery General Design Requirements.

a. All batteries shall be capable of being easily electrically disconnected and/or removed.

b. Battery connectors shall be designed to prevent reverse polarity.

c. Diodes shall be used to prevent reverse current. **NOTE:** Diodes may be placed in the battery or in external circuitry.

d. If a battery is not connected to the system, the battery terminals or connector plug shall be taped, guarded, or otherwise given positive protection against shorting.

e. Identification. Each battery shall be permanently identified with the following information:

1. Component name
2. Type of construction
3. Manufacturer identification
4. Part number
5. Lot and serial number
6. Date of manufacture

3.14.1.6.2 EGSE and Flight Hardware Lithium Batteries. The following requirements are applicable to lithium batteries used in flight hardware and EGSE:

a. All lithium battery designs shall be reviewed and approved by Range Safety prior to arrival, usage, packing, storage, transportation, or disposal on the Ranges. **NOTE:** Batteries that have an Underwriter's Laboratory (UL) listing and are intended for public use are exempt from these requirements.

b. The following safety devices shall be incorporated into the lithium battery design:

1. Thermistors or fuses shall be used for each battery output.

2. Internal diodes shall be placed between each cell, unless proven by test that any single cell cannot be driven into reversal by the remaining cells.

3. Cells in series shall have shunt diode protection.

4. Parallel rows of cells shall have blocking diodes.

c. Each electrical safety device shall have a specific quality control program approved by Range Safety.

d. Safety critical steps and processes shall be identified during development for the manufacturing process. **NOTE**: These points in manufacturing shall be reviewed by Range Safety and a determination made of what points require Range Safety approval prior to change and what points the Range User can approve with just notification to Range Safety after the fact.

e. Batteries shall be designed not to create a catastrophic hazard when the safety tests described in the **Ordnance Systems** section of this Chapter are performed.

3.14.2 EGSE Design Requirements

3.14.2.1 EGSE Design Standards

The following requirements supplement the requirements specified in the **Electrical and Electronic Ground Support Equipment and Flight Hardware General Design Requirements** of this Chapter, NFPA 70, and MIL-HDBK-454, Requirement 1.

3.14.2.2 EGSE Switches and Controls

a. A clearly labeled main power switch and power indicator light located on ground support equipment shall cut off power to all circuits in the equipment. A power indicator light shall be provided. If fault isolation switches are incorporated, they shall not operate independently of the main power switch.

b. Power switches shall be located so that accidental contact by personnel will not place equipment in operation.

c. All switches and controls shall be clearly marked.

d. Switches and controls shall be sufficiently separated and protected if they could be inadvertently mistaken and actuated, creating a hazardous condition.

e. Critical switches that can produce or induce hazardous conditions, if inadvertently activated, shall have a protective cover over them.

3.14.2.3 EGSE Circuit Protection

a. Fuses, circuits breakers, and other protective devices are required for EGSE primary circuits.

b. Protective devices shall be connected to the load side of the main power switch unless neutral power sensing is essential for proper protection of the equipment.

c. Protection shall be provided in each of the three ungrounded conductors of all 3-phase EGSE motors so that failure of one conductor shall result in de-energizing all three conductors.

d. All fuses, circuit breakers, resets, or other safety devices shall be located for easy access.

e. Circuit breaker trips shall be detectable by visual inspection.

f. Replaceable components and test points shall be easily accessible.

g. Electrical fuse and switch boxes shall be marked on the outside or inside cover to show the voltage present, rated fuse capacity, and EGSE that the circuit controls.

h. Each redundant EGSE circuit shall have its own circuit breaker or fuse.

i. Each circuit shall not have the capability to inhibit by loss of control more than one safety critical control device.

j. Megohm meter (megger high voltage resistance meters) shall be current limited by the use of fuses or equivalent devices depending on application.

3.14.2.4 EGSE Cables

EGSE cables shall not share the same trench as propellant lines.

3.14.2.5 EGSE Batteries

a. Sufficient ventilation shall be provided for EGSE batteries to ensure concentrations of vapor do not reach 25 percent of the LEL.

b. Polarity of EGSE battery terminals shall be marked.

3.14.2.6 EGSE Battery Charging Equipment

a. Battery charging EGSE shall be current limited by design.

b. The battery charging rate shall not be able to initiate or sustain a run-away failure of the battery.

c. A temperature monitoring system shall be used in addition to other methods of charge control.

d. Analysis or testing shall be conducted to demonstrate compliance with the above requirement.

3.14.2.7 Fixed and Portable EGSE in Hazardous Locations

a. At a minimum, electrical equipment and its installation shall comply with the requirements of the most recent edition of the NFPA 70 or the regulations of OSHA, whichever are more restrictive.

b. Any electrical equipment that is not specifically labeled for the purpose or conditions of operation intended by a recognized testing agency, or that is not manufactured or installed to meet the electrical classification of the area in which the equipment is to be operated shall be approved by Range Safety prior to putting the equipment in service.

3.14.2.7.1 Definition of Hazardous (Classified) Locations. Hazardous (classified) locations are defined in Article 500 of the NEC; however, some explosives and propellants are not covered. For Range installations, the following paragraphs define the minimum requirements to be applied in the definition of locations in which explosives, pyrotechnics, or propellants are or are expected to be present. These requirements shall be followed unless less stringent classifications are justified and approved as part of the design data submittal process. Range Safety and the Fire Marshal shall approve all potential critical facility hazardous location designations. (See Appendix 3C for hazardous area classifications.)

a. Class 1, Division 1

1. Locations in which flammable liquids, vapors, or gases may be present in air during normal operations

2. Locations in which ignitable concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage

3. Locations in which the breakdown or faulty operation of equipment or processes might release ignitable concentrations of flammable gases or vapors and might also cause simultaneous failure of electrical equipment

4. As a baseline, these include the following locations:

(a) Within 25 ft of any vent opening unless the discharge is normally incinerated or scrubbed to non-flammable conditions (less than 25 percent of LEL). This distance may be increased if the vent flow rate creates a flammability concern at a distance greater than 25 ft.

(b) Below grade locations in a Class 1, Division 2 area.

b. Class 1, Division 2

1. Locations in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined in closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or system or in case of abnormal operation of equipment

2. Locations in which ignitable concentrations of gases or vapors are normally prevented by positive mechanical ventilation and which might become hazardous through failure of abnormal operations of ventilation equipment

3. Locations adjacent to a Class 1, Division 1 location and to which ignitable concentrations of gases or vapors might occasionally be communicated unless communication is prevented by adequate positive pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided. **NOTE 1**: This classification usually includes locations where volatile flammable liquids or flammable gases or vapors are used but, in the judgment of Range Safety and the Fire Marshal, would become hazardous only in case of an accident or of some unusual operating condition. The quantity of flammable material that might escape in case of an accident, the adequacy of ventilating equipment, the total area involved, and the record of the Range User with respect to explosions or fires are all factors that merit consideration in determining the classification and extent of each location. **NOTE 2**: Piping without valves, checks, meters, and similar devices would not ordinarily introduce a hazardous condition even though used for flammable liquids or gases. Locations used for the storage of flammable liquids or of liquefied or compressed gases in sealed containers would not normally be considered hazardous unless also subject to other hazardous conditions. **NOTE 3**: As determined by Range Safety and the Fire Marshal, locations may actively change classification depending upon the flammable fluid system activity and configuration. For these types of locations, fixed or permanently installed electrical equipment shall be designed for the worst case hazardous environment. **NOTE 4**: Portable electrical equipment shall be designed for the worst case hazardous environment in which it will be used. Portable equipment that is not designed for use in a particular hazardous environment shall not be in that environment or shall be locked out from use in that environment.

4. As a baseline, Class 1, Division 2 locations include the following equipment or areas:

(a) Storage vessels (including carts and drums) - 25 ft horizontally and below to grade and 4 ft vertically above the vessel (25 ft in any direction for hydrogen)

(b) Transfer lines - 25 ft horizontally and below to grade and 4 ft above the line (25 ft in any direction for hydrogen)

(c) Launch vehicle (liquid fueled vehicle, stages, or payloads) - 100 ft radius horizontally from and 25 ft vertically above (100 ft for hydrogen) the highest leak or vent source and below the vehicle to grade

(d) Enclosed locations such as rooms, work bays, and launch complex clean rooms that are used to store and handle flammable and combustible propellants when the concentration of vapors inside the room resulting from a release of all fluids stored and handled equals the lowest explosive limit. **NOTE:** The quantity of fluids used in the analysis shall be the maximum amount allowed in the explosives site plan.

c. Hazardous Commodity Groups. Hazardous commodities are grouped by similar characteristics. These fuels shall be categorized as follows:

1. Group B - Liquid or gaseous hydrogen

2. Group C - Hypergolic fuels such as Hydrazine (N_2H_4), Monomethyl Hydrazine (MMH), Unsymmetrical Dimethyl Hydrazine (UDMH), Aerozine 50 (A50)

3. Group D - Hydrocarbon fuels Rocket Propellant (RP) and Jet Propellant (JP)

4. Group D - Oxidizers. Oxidizers shall be considered Group D hazardous substances in addition to the fluids listed in Section 500-3 of the NEC

d. Exposed Solid Propellants. The atmosphere within 10 ft of exposed solid propellant shall be classified as a Class 1, Division 2, Group D location. Solid rocket motors are considered exposed in the following situations:

1. The motor nozzle is not attached and the aft end of the motor does not have a cover

2. The motor nozzle is attached but does not have a nozzle plug

3. The unassembled motor segments do not have front and rear covers

4. The igniter is removed from the motor and cover is not provided

3.14.2.7.2 Electrical Systems and Equipment Hazard Proofing. Electrical systems and equipment used in hazardous locations shall be designed and listed for the locations in accordance with the following requirements:

a. Explosion proof apparatus shall meet the requirements of the NEC for Class I, Division 1, and be listed and labeled by a nationally recognized testing laboratory, such as UL or Factory Mutual Corporation (FM).

b. Non-incendive apparatus shall meet the requirements of NEC Article 501 and are restricted to installations in Class I, Division 2 locations only. They shall be listed and labeled by a nationally recognized testing laboratory such as UL or FM.

c. Intrinsically safe equipment intended for Class I, Division 1 locations shall meet the requirements of NEC Article 504 and UL 913 and be listed and labeled by a nationally recognized testing laboratory such as UL or FM.

d. The use of purged and pressurized electrical enclosures designed in accordance with NFPA 496 for the purpose of eliminating or reducing the hazardous location classification as defined in Article 500 of the NEC is acceptable with the following additional requirements:

1. The purged and pressurized enclosure shall be maintained at a nominal 1/2 in. of water unless a lower pressure is approved by Range Safety. In no case shall the pressure in the enclosures be less than 1/10 in. of water.

2. Rooms into which unprotected personnel may enter shall be purged with air only.

3. Purged rooms and enclosures shall be provided with an audible alarm set to trigger when the pressure drops below 1/4 in. water.

e. Equipment inspected and tested to other government standards such as MIL-STD-810 may be used if approved by Range Safety in coordination with Civil Engineering.

f. Exterior Interconnecting Cable

1. Exterior interconnecting cable installed in the “open” is acceptable for interconnecting electrical equipment in a hazardous location. **NOTE:** *Open* refers to open trays or raceways that cannot trap gases when installing exterior-type to interconnect electrical equipment in a hazardous location

2. Cable installation shall comply with the requirements of Article 501-4 of the NEC.

3.14.3 Electrical and Electronic Flight Hardware

3.14.3.1 Electrical and Electronic Flight Hardware Design Standards

Airborne electrical and electronic equipment shall be designed to meet the intent of NEC 501 to the maximum extent possible. **NOTE:** The intent of NEC 501 is normally provided by hermetic sealing.

3.14.3.2 Flight Hardware Electromechanical Initiating Devices and Systems

a. Electromechanical initiating devices and systems, including NEIs, are used for such purposes as structure deployment or actuation release mechanisms.

b. Electromechanical initiating devices and systems shall be evaluated to determine the severity of the hazard (Category A or B).

c. Design, test, and data requirements shall be determined by Range Safety on a case-by-case basis.

d. At a minimum, the system safety fault tolerances described in the **System Design Policy** section of this Chapter and the initiating ordnance design requirements shall be addressed.

3.14.3.3 Flight Hardware Batteries

a. Flight battery cases shall be designed to an ultimate safety factor of 3 to l with respect to worst case pressure build-up for normal operations.

1. This pressure build-up shall take into account hydraulic and temperature extremes.

2. Batteries that have chemically limited pressure increases such as nickel-hydrogen chemistries and whose battery/cell case can be designed to withstand worst case pressure build-up in abnormal conditions such as direct short and extreme temperatures, can reduce the safety factor to 2:1 (ultimate) and 1.5:1 yield. Lower factors of safety determined by an Range Safety approved fracture mechanics analysis can be used on a case-by-case basis for nickel-hydrogen chemistries.

b. Sealed batteries shall have pressure relief capability unless the battery case is designed to a safety factor of at least 3 to 1 based on worst case internal pressure.

1. Pressure relief devices shall be set to operate at a maximum of 1.5 times the operating pressure and sized so that the resulting maximum stress of the case does not exceed the yield strength of the case material.

2. Nickel-hydrogen batteries and/or cells that are proven by test to withstand worst case pressure build-up in abnormal conditions such as direct short and thermal extremes that can be experienced when installed with no reliance on external controls such as heaters and air conditioning are not required to have pressure relief capability.

3.14.4 Test Requirements for Lithium Batteries

Unless otherwise agreed to by Range Safety, the following tests shall be performed prior to the use or storage of lithium batteries at the Ranges. **NOTE:** These tests are likely to cause violent reactions, so all possible safety precautions shall be observed.

3.14.4.1 Lithium Battery Constant Current Discharge and Reversal Test

a. The constant current discharge and reversal test shall determine if the pressure relief mechanism functions properly or case integrity is sustained under circumstances simulating a high rate of discharge.

b. The test shall be performed according to the following criteria:

1. The test shall consist of a constant current discharge using a DC power supply.

2. The fusing of the battery shall be bypassed (shorted).

3. The discharge shall be performed at a level equal to the battery fuse current rating and the voltage of the battery.

4. After the battery voltage reaches zero volts, the discharge shall be continued into voltage reversal at the same current for a time equivalent to l.5 times the stated ampere-hour capacity of the battery pack.

5. Voltage, pressure, and temperature shall be continuously monitored and recorded.

3.14.4.2 Lithium Battery Short Circuit Test

a. The short circuit test shall determine if the pressure relief mechanism functions properly under conditions simulating a battery short circuit failure mode; or if a pressure relief mechanism is not provided, case integrity shall be determined under conditions simulating a battery short circuit failure mode.

b. The test shall be performed according to the following criteria:

1. After all internal electrical safety devices have been bypassed, the battery shall be shorted through a load of 0.0l ohm or less, leaving the load attached for not less than 24 h.

2. Voltage, current, pressure, and temperature shall be continuously monitored and recorded.

3.14.4.3 Lithium Battery Drop Test

A drop test shall be performed according to the following criteria:

a. The battery in the activated state shall be dropped from a 3-ft height to a concrete pad on the edge of the battery, on the corner of the battery, and on the terminals of the battery.

b. The battery shall not vent or start a hazardous event when dropped.

c. A physical analysis shall be performed after the drop test to determine what handling procedures are required to safely dispose of the batteries if dropped on the Ranges.

NOTE: Other tests may be required by Range Safety depending upon design, storage, operating environments and other criteria. If required, additional tests shall be identified by Range Safety during the cDR and PDR. Manufacturing lot acceptance tests may be required of safety devices in the battery design to ensure safety critical functions have not been altered.

3.14.5 Electrical and Electronic Equipment Data Requirements

The following electrical and electronic equipment design data shall be incorporated in the MSPSP: (See Appendix 3A for guidance.)

3.14.5.1 EGSE and Flight Hardware Battery Design Data

a. Design versus actual operating parameters of cells and battery

b. Cell chemistry and physical construction

c. Cell vent parameters

d. Toxic chemical emission of cells and evaluation of hazards

e. EPA classification of battery

f. DOT classification of battery

g. Physical and electrical integration of cells to form the battery

h. Description of safety devices

i. Case design including vent operation and cell and battery case housing yield point

j. A description of all Range operations including packing, transportation, and storage configuration; activation; installation; checkout; charging; usage; removal; and disposal

k. Identification of the hazards associated with each activity in *j* above and the safety controls that shall be in effect

l. Manufacturing qualification and acceptance testing results that are considered safety critical

m. Battery size and weight

n. Specification of the system that uses the battery

o. A description of the EGSE used for packing, transportation, and storage; activation; installation; checkout; charging; usage; removal; and disposal of the battery

p. Lithium battery test results

3.14.5.2 EGSE Design Data

a. Identification of EGSE and its use

b. A description of how faults in the EGSE circuitry that can create a hazardous condition are prevented from propagating into the flight system

c. A description of how inadvertent commands that can cause a hazardous condition are prevented

d. Identification of potential shock hazards

e. A description of how the intent of the NFPA is met with respect to hazardous atmospheres

f. Identification of all non-explosion proof equipment powered up during and after propellant loading

g. For explosion proof and intrinsically safe equipment approved by a nationally recognized testing laboratory, the following information shall be provided:

1. Manufacturer

2. Model number

3. Hazardous location class and group

4. Operating temperature

h. For any explosion proof equipment or component not having a fixed label from a nationally recognized testing laboratory, the data and certification shall be available for inspection in the facility of use.

i. Test data and certification on custom or modified equipment that can not be certified by a nationally recognized testing laboratory for explosion proof equipment

j. Test results for all Range User designed, built, or modified intrinsically safe apparatus as required by a nationally recognized testing laboratory in accordance with UL 913, *Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1 Hazardous (Classified) Locations*

k. Results of the bent pin analysis performed on all safety critical or hazardous system connectors that cannot be verified as a good mate after final connection.

3.14.5.3 Electrical and Electronic Flight Hardware Data Requirements

a. A brief description of power sources and the power distribution network, including schematics and line drawings of the distribution network

b. A description of how faults in electrical circuitry are prevented from propagating into hazardous subsystems, including such information as dedicated power sources and buses, use of fuses, and wiring sizing

c. A description of how inadvertent commands that can cause a hazardous condition are prevented

d. Identification of potential shock hazards

e. A description of how the intent of hazard proofing is met for electrical and electronic systems

f. Complete grounding and bonding methodology

g. Results of the bent pin analysis performed on all safety critical or hazardous system connectors that cannot be verified as a good mate after final connection.

3.15 MOTOR VEHICLES

This section provides the design, test, and documentation requirements for motor vehicles, tankers, and trailers used to transport critical hardware or bulk hazardous materials such as toxics, flammables, and combustibles and explosives on CCAS/VAFB roads and tracks. It also applies to all forklifts, regardless of the loads being handled on the Ranges.

3.15.1 Motor Vehicles, Tankers, and Trailers

3.15.1.1 Motor Vehicle, Tanker, and Trailer General Design Requirements

a. Motor vehicles, tankers, and trailers shall comply with applicable DOT and DoD requirements for transportation on public highways and rails.

b. Motor vehicles, tankers, and trailers that do not meet DOT and DoD public transportation requirements shall not be permitted to transport hazardous materials on the Ranges unless the vehicle is covered by a formal DOT and/or DoD exemption.

c. If the motor vehicle, tanker, or trailer is not exempted from DOT requirements, the following data shall be submitted to Range Safety for review and approval prior to using the vehicles on the Ranges:

1. Design, test, and NDE inspection requirements for vehicles

2. Stress analysis

3. Single failure point analysis

4. FMECA in accordance with MIL-STD-1543

5. Clear identification of areas of compliance and non-compliance with similar, DOT approved, vehicles

6. Engineering documentation such as analyses, tests, and inspections that justifies acceptance of these DOT noncompliances based on “equivalent safety” or “meets DOT intent” criteria

3.15.1.2 Trailers Used to Transport Critical Flight Hardware Design

a. Trailers and their ancillary support equipment such as outriggers and support stands shall be designed with a yield factor of safety of at least 2.

b. Load test tags shall be attached to the trailer and marked with the following minimum information:

1. Part number

2. Date of most recent load test (or date of next load test)

3. Weight of test load

4. Rated load

5. Date of most recent NDE (or date of next NDE)

c. Load test tags shall be accessible for inspection.

d. A single failure point (SFP) analysis shall be performed.

3.15.1.3 Trailers Used to Transport Critical Flight Hardware Tests

3.15.1.3.1 Critical Flight Hardware Trailer Initial Tests. At a minimum, the following critical tests shall be performed on trailers used to transport critical flight hardware on Range roads. These tests shall be performed prior to first operational use at the Ranges:

a. The trailer shall be static proof tested to 125 percent of rated load. **NOTE:** The rated load shall include the dynamic load.

b. A road test shall be taken over an actual Range route at maximum allowable speed with 100 percent of rated load on the trailer. **NOTE:** Trailers will be instrumented to verify the proper dynamic loading was taken into account.

c. Volumetric and surface NDI shall be performed on all SFP components and SFP welds prior to the proof load test and after the road test.

d. Volumetric and surface NDI shall be performed on 10 percent of non-SFP welds located in load path.

3.15.1.3.2 Critical Flight Hardware Trailer Periodic Tests. At a minimum, the following tests shall be performed on trailers used to transport flight hardware (hazardous or non-hazardous) on the Ranges every four years. Unless otherwise agreed to by Range Safety, these tests shall also be performed after a trailer has been modified or repaired:

a. The trailer shall be proof tested to 125 percent of rated load.

b. Visual and surface NDE shall be performed on all SFP components and SFP welds after the proof load test.

c. Volumetric NDE shall be performed on all modified and/or repaired SFP components and SFP welds prior to and after the load test.

3.15.1.4 Motor Vehicles, Tankers, Trailers, and Critical Flight Hardware Trailer Data Requirements

The following initial and recurring data requirements shall be submitted to Range Safety for review and approval as part of the MSPSP:

3.15.1.4.1 Motor Vehicle, Tanker, and Trailer Initial Data. The following data shall be submitted to Range Safety for review and approval prior to the first operational use of vehicles used to transport hazardous material or flight hardware on the Ranges:

a. Documentation certifying that motor vehicles and tankers comply with DOT requirements or are formally exempted by DOT.

b. If the DOT certification or exemption documentation is not available, the following information is required:

1. Design, test, inspection requirements

2. Stress analysis

3. Single failure point analysis

4. FMECA

5. Comparison analysis with similar DOT approved vehicle

6. "Equivalent safety" (meets DOT intent) analysis

3.15.1.4.2 Critical Flight Hardware Trailer Initial Data. The following data shall be submitted for trailers used to transport critical flight hardware (hazardous or non-hazardous):

a. Stress analysis
b. SFP analysis
c. Initial proof load test plan and test results
d. Initial road test plan and test results
e. NDE plan and test results for SFPs

3.15.1.4.3 Critical Flight Hardware Trailer Recurring Data. The following data shall be submitted to Range Safety for review and approval prior to the first periodic testing of trailers used to transport critical flight hardware:

a. Periodic proof load test plan and test results
b. NDE plan and test results for SFPs

3.15.2 Forklifts

NOTE: Before using a forklift to lift or move critical loads, consideration shall be given to the use of facility cranes.

3.15.2.1 Forklift Design Standards

a. All forklifts shall be designed in accordance with ANSI/ASME B56.1 and 29 CFR 1920.178.

b. Additional requirements:

1. Forklifts with internal combustion engines shall meet UL 558.

2. Electric battery operated forklifts shall meet UL 583.

3. Forklifts to be used in locations classified by Article 500 of the NEC shall meet the requirements of NFPA 505. Tires and other components shall not be replaced with tires and other components not approved for the specific application and/or environment.

4. Forklifts used to transport explosives and propellants or operate in explosive and propellant locations shall also meet the requirements of AFMAN 91-201 and DoD 6055.9-STD.

3.15.2.2 Forklift General Design Requirements

a. All forklifts shall be equipped with overhead guards.

b. All forklifts shall be designed with shoulder-high wing safety seats with seat belts.

c. All forklifts shall be designed with dead-man controls.

d. Personnel platforms attached to forklifts shall be designed and tested in accordance with the **Personnel Platforms** section of this Chapter.

e. All forklifts shall be clearly marked with 2-in. letters indicating maximum load capacity at maximum elevation.

f. Critical loads shall not exceed 75 percent of the forklift rated capacity.

3.15.2.3 Gasoline and Diesel Powered Forklifts

a. Deflector plates shall be installed to prevent overflow from the fuel tank from reaching the engine or exhaust system.

b. Flash screens shall be installed in the fuel line of both gasoline and diesel powered forklifts.

c. Diesel powered forklifts shall have an emergency shutoff valve installed in the fuel line at a convenient and visible location.

3.15.2.4 Battery Powered Forklifts

a. All electrical cables shall be mounted so that they cannot catch or snag on stationary objects.

b. Battery boxes shall be securely fastened and ventilated to ensure explosive gas mixture buildup does not occur.

c. The main service switch shall be located so that it can be reached from the driver position.

3.15.2.5 Forklift Tests

All forklifts shall be tested in accordance with ANSI/ASME B56.1.

3.15.2.6 Forklift Data Requirements

The following data shall be submitted to Range Safety for review and approval prior to the first use of a forklift at the Ranges. The data shall be incorporated in the MSPSP:

a. Certification that the forklift has been designed and tested in accordance with applicable national standards such as ANSI/ASME B56.1, UL 558, and UL 583

b. For personnel platforms on forklifts:

1. Stress analysis

2. SFP analysis

3. NDI plan and test results for SFP components and welds

4. Proof load test plan and test results

5. For forklifts used to lift or move critical loads, maintenance plans shall be submitted for review and approval.

3.16 COMPUTING SYSTEMS AND SOFTWARE

This section provides safety design requirements and guidelines for the design and development of all systems such as flight and ground in which computing systems have or potentially have safety critical applications. Unless specifically excluded and approved by Range Safety, all safety critical computing systems associated with the handling, checkout, test, or launch of missiles or space vehicles at the Ranges shall be designed in accordance with the requirements in this section. These requirements include safety critical computing systems used in prelaunch assembly operations such as software controlled cranes.

3.16.1 Determination of Software Safety Critical Functions

a. Software used to control or monitor the functioning of safety critical hardware shall be considered a software safety critical function (SSCF).

b. Software used to or having the capability to monitor or control hazardous systems shall be considered an SSCF.

c. Software associated with fault detection of safety critical hardware and/or software shall be considered an SSCF. **NOTE:** *Fault* is defined as the manifestation of an error in software. The term *fault detection* includes software associated with fault signal transmission.

d. Software responding to the detection of a safety critical fault shall be considered an SSCF.

e. Flight Termination System (FTS) software shall be considered an SSCF.

f. Processor interrupt software associated with previously designated SSCF shall be considered an SSCF.

g. Computation of safety critical data used in a previously designated SSCF shall be considered and SSCF.

NOTE: It is recommended that SSCFs are identified and agreed to with Range Safety early in the program. Boundaries defining what is included and excluded from each SSCF should be docu-mented.

3.16.2 General Safety Design Requirements

The following requirements shall apply to all SSCFs.

3.16.2.1 Central Processing Unit/Firmware

a. Central Processing Unit (CPU) functionality shall be validated for intended use and environment. Such validation may be based upon experience and/or testing.

b. CPU throughput shall not exceed 80 percent (not exceeding 70 percent is desirable).

c. CPUs shall either separate instruction and data memories and busses or separate program memory and data memory through memory protection hardware, segment protection, or page protection.

d. SSCF flight architecture shall protect against CPU Single Event Upset (SEU) at altitudes of 30,000 ft and above. This may be accomplished through redundancy, error correcting memory, voting between parallel CPUs, or other approved approaches.

e. Design of firmware and installation procedures should minimize the potential for damage to the circuits due to mishandling, electrostatic discharge, or normal or abnormal storage environments.

3.16.2.2 Power

a. The system shall power up in a safe state.

b. The system shall not enter an unsafe or hazardous state after an intermittent power transient or fluctuation.

c. The system shall gracefully degrade to a secondary mode of operations or shutdown in the event of a total power loss so that potentially unsafe states are not created.

3.16.2.3 Failure Detection

a. An initialization test that verifies the following shall be incorporated in the design:

1. The system is in a safe state and functioning properly prior to initiation of hazardous activities

2. Continuity and proper functioning of SSCF circuits, components, inhibits, interlocks, exception limits, and safing logic are tested to ensure safety operation

3. Memory integrity

4. Program loads

b. The system shall periodically verify:

1. That safety critical hardware and SSCF, including safety data transmission are operating correctly

2. That safety data transmission has not been corrupted

3. The validity of real-time SSCF data

c. The software shall be capable of detecting the following input/output errors:

1. Improper entries

2. Improper sequences of entries

3. Improper sequences of operations

4. Invalid output

5. Timing

3.16.2.4 Failure Response

a. If a failure or error is detected within a ground/prelaunch processing SSCF or associated safety critical hardware, the system shall:

1. Be designed to revert to a safe state

2. Provide provisions for safing hardware subsystems under the control of software

3. Reject erroneous input

4. Ensure the logging of all detected SSCF related system errors

5. Notify the operator if an ARM and SAFE logic error pattern, other than the ARM and SAFE codes, is present.

6. Initiate Anomaly Alerts

(a) Anomalies shall be prioritized; for example, warning/caution/advisory.

(b) Anomalies of the same priority should be grouped together; for example, all warnings displayed first, cautions next, and advisories last.

(c) The most recent anomaly should be displayed at the top of the priority subgroup.

(d) The display shall support reporting multiple anomalies. Details of each anomaly may be accessed with a single action; in other words, expand each anomaly summary into full write-up delineating actions automatically taken and recommended actions for the operator to take.

(e) The display shall differentiate between read and unread anomaly alerts.

(f) Anomaly alerts shall be cleared after predefined operator input. Such inputs shall provide feedback of the corrective actions taken and confirm corrective action states.

b. If a failure or error is detected within a flight SSCF or associated safety critical hardware, the system shall:

1. Maintain the FTS in an ARMED state throughout the flight even if errors are detected

2. Reject erroneous input

3. Ensure all detected SSCF (FTS) related system errors are transmitted via telemetry to the range

4. Notify the operator if an ARM or SAFE logic pattern other than ARM or SAFE code is present.

3.16.2.5 Testing and Maintenance

3.16.2.5.1 Non-Operational Hardware and Software.

a. If non-operational hardware, such as test sets and simulators, or software is required for testing or maintenance, the system shall be designed so that identification of such equipment is fail-safe.

b. Operational hardware or software identification shall not be inadvertently identified as non-operational.

3.16.2.5.2 Interlocks and Inhibits.

a. Interlocks shall be provided to preclude hazards to personnel maintaining or testing the system.

b. Provisions shall prevent interlocks from being inadvertently overridden.

c. Where interlocks must be overridden, disabled, removed, or bypassed to perform tests, they shall:

1. Not be left in overridden state once the system is restored to operational use

2. Not be autonomously controlled by a computing system

3. Display the status of the interlocks on the safety console and/or the test/launch conductor console

4. Verify the restoration of the interlocks prior to resuming normal operations.

3.16.2.6 EMI/ESD

The system design shall provide protection against harmful effects from electromagnetic radiation, or electrostatic discharge for the sensitive components of the SSCF computer system.

3.16.2.7 Operator Console

a. The system shall be designed so that the operator may cancel current processing with a single action and have the system revert to a known safe state. **NOTE 1:** The action may consist of pressing two keys at the same time. **NOTE 2.** In-flight FTS "safe state" may either be in a SAFE or ARMED mode.

b. The system shall be designed so that the operator may exit potentially unsafe states to a known safe state with a single action. **NOTE:** The action may consist of pressing two keys at the same time.

c. Two or more unique operator actions shall be required to initiate any potentially hazardous function or sequence of functions.

d. Actions required shall be designed to minimize the potential for inadvertent actuation.

e. Operator displays, legends, and other interactions shall be clear, concise, and unambiguous.

f. The software shall provide positive confirmation of valid data entry or actions taken; for example, the system shall provide visual and/or aural feedback to the operator so the operator knows that the system has accepted the action and is processing it.

g. The system shall provide feedback for SSCF actions not executed.

h. The system shall provide a real-time indication that it is functioning.

i. Real-time processing functions requiring several seconds or longer shall provide a status indicator to the operator during processing. **NOTE:** Indication should confirm that the commanded action has occurred thus providing the operator with a closed-loop indication. This should not merely be a “signal has been sent” status.

j. Multiple devices and logical paths shall be provided to ensure that a single failure/error cannot prevent the operator from taking safing actions.

k. Error messages that distinguish safety critical states/errors from non-safety critical states/errors shall be provided.

3.16.3 Software Development

The following requirements are applicable to all SSCFs.

3.16.3.1 Software Development Process

a. Desk audits, peer reviews, static analysis, and dynamic analysis tools and techniques shall be used to verify implementation of SSCF design requirements in the source code and system.

b. Reviews of the software source code shall ensure that the code and comments within the code agree.

c. Object code patches shall be prohibited.

3.16.3.2 Coding Standards

3.16.3.2.1 Timers.

a. Watchdog timers or similar devices shall be provided to ensure that the microprocessor or computer is operating properly.

b. Watchdog timers or similar devices shall be designed so that SSCF software cannot enter an inner loop and reset the timer or similar device as part of that loop sequence.

c. SSCF timing functions shall be controlled by the computer.

d. SSCF timing values shall not be modifiable by the operator from system consoles.

e. SSCF timer values shall be verified and shall be examined for reasonableness for the intended function.

3.16.3.2.2 Modular Code.

a. SSCF software design and code shall be modular.

b. The number of program modules containing SSCF shall be minimized where possible within the constraints of operational effectiveness, computer resources, and good software design practices.

c. Modules shall have one entry and one exit point.

d. SSCF software should be segregated from non-SSCF software.

3.16.3.2.3 Loops.

a. Loops shall not exceed a predefined constant maximum execution time.

b. Feedback loops shall be designed so that the software cannot cause a runaway condition due to the failure of a feedback sensor.

c. Branches into loops shall not be used.

d. Branches out of loops shall lead to a single exit point placed after the loop within the same module.

3.16.3.2.4 Object Code.

a. STOP instructions shall not be used in operational SSCF object code.

b. HALT instructions shall not be used in non-executive operational SSCF object code.

c. After a task has been HALTED, the executive shall restart CPU task processing no later than the start of the next computing frame.

d. WAIT instructions may be used where necessary to synchronize input/output where appropriate handshake signals are not available.

e. The system design shall prevent unauthorized or inadvertent access to or modification of SSCF software (source or assembly) and SSCF object code.

f. The system design shall prevent self-modification of the SSCF object code.

g. SSCF operational program loads shall not contain unused executable codes; in other words, Dead Code.

h. SSCF operational program loads shall not contain unreferenced variables.

3.16.3.2.5 Data.

a. SSCFs shall exhibit strong data typing.

b. SSCFs shall not employ a logic “1” and “0” to denote the SAFE and ARM (potentially hazardous) states.

c. The ARM and SAFE states shall be represented by at least a unique 4-bit pattern.

d. The SAFE state shall be a pattern that cannot represent the ARM pattern as a result of a 1- or 2-bit error.

3.16.3.2.6 Interfaces. **NOTE:** These requirements include any SSCF interface between CPUs and hardware input/output devices.

a. Parity checks, checksums, cycle redundancy checks, or other data verification techniques shall be used for verification of correct data transfer.

b. Data transfer messages shall be of a predetermined format and content.

c. Limit and reasonableness checks shall be performed on all SSCF inputs and outputs.

d. Functions requiring two or more SSCF signals (such as ARM and FIRE) shall not receive all of the necessary signals from a single register or input/output port.

e. Functions requiring two or more SSCF signals (such as ARM and FIRE) shall not be generated by a single software module.

3.16.3.2.7 Logic.

a. SSCF conditional statements shall have all required conditions satisfied; there shall not be a potential for unresolved input to the conditional statement.

b. Decision statements in SSCF shall not rely on inputs of all 1s or 0s, particularly when this information is obtained from external sensors.

c. Flags and variable names shall be unique and shall have a single purpose.

d. Files shall be unique and shall have a single purpose.

e. Scratch files shall not be used for storing or transferring SSCF information, data, or control functions between processes.

f. The software shall contain only those features and capabilities required by the system. The SSCF programs shall not contain undocumented or unnecessary features.

g. Indirect addressing methods shall not be used unless absolutely necessary. When used the address shall be verified as being within acceptable limits prior to execution of SSCF operations. Data written to arrays in SSCF operations shall have the address boundary checked by the compiled code.

h. The results of an SSCF program shall not be dependent on the time taken to execute the program or time at which execution is initiated.

i. SSCF software shall be designed so that the full scale and zero representations of the software are fully compatible with the scales of any digital-to-analog, analog-to-digital, digital-to-synchro, and/or synchro-to-digital converters used in the system.

j. One-to-one assignment statements shall not be used in SSCF code.

3.16.3.2.8 Memory.

a. Static Memory Allocation

1. All ground or prelaunch process memory not used for or by the operational program shall be initiated to a pattern that will cause the system to revert to a safe state if executed.

2. All flight processor memory not used for or by the operational program shall be initiated to a pattern that will cause the system to revert to a predefined state if executed. This predefined state shall not stop the CPU from operating. **NOTE.** Predefined state shall not change the FTS operating mode; for example, ARMED shall not be SAFED.

b. Dynamic Memory Allocation. Memory usage shall not exceed 85 percent. **NOTE.** Assumes average memory usage but is verified by testing against projected worst case to ensure protection from memory saturation as a result of memory leakage.

c. Random numbers, HALT, STOP, WAIT, or NO-OPERATION instructions shall not fill processing memory.

d. Data or code from previous overlays or loads shall not be allowed to remain.

e. Overlays of SSCF software shall all occupy the same amount of memory.

f. Safety kernels shall be resident in nonvolatile read only memory (ROM) or in protected memory that cannot be overridden by the computing system.

3.16.3.3 Configuration Control

a. Configuration control shall be established as soon as a practical software baseline is established.

b. A Software Configuration Control Board (SCCB) shall approve changes to configuration controlled software prior to their implementation.

c. A member from the system safety engineering team shall be a member of the SCCB and tasked with the responsibility for evaluation of all software changes for their potential safety impact.

d. A member of the hardware Configuration Control Board (CCB) shall be a member of the SCCB and vice versa to keep members apprised of hardware/software changes and to ensure that hardware/ software changes do not conflict with or introduce potential safety hazards due to hardware/software incompatibilities.

e. All software changes shall be coded into the source code, compiled, and tested prior to being introduced into operational equipment.

f. Firmware changes shall be issued as a fully functional and tested circuit card.

g. Electrically Erasable Programmable Read Only Memory (EEPROM):

1. EEPROM changes shall pass hardware/ software functionality testing on like hardware prior to installation onto the system.

2. EEPROM changes shall contain an embedded version identification number and be validated via checksum.

h. All SSCF software and associated interfaces shall be under configuration control.

3.16.3.4 Software Analyses

a. Internal Independent Validation & Verification (IIV&V) or similar formal process shall be used to ensure safety design requirements have been correctly and completely implemented for SSCF code.

b. Conditional statements shall be analyzed to ensure that the conditions are reasonable for the task and that all potential conditions are satisfied and not left to a default condition.

c. Comment statements shall be adequately describe the functionality of the code.

d. Test results shall be analyzed to identify potential safety anomalies that may occur. **NOTE:** It is recommended that hazards be investigated from a system level with hardware and software components.

3.16.3.5 Software Testing

SSCF software testing shall include the following:

a. GO/NO-GO path testing (functioning properly/not functioning properly)

b. Reaction of software to system (hardware, software, or combination of hardware and software) errors or failures

c. Boundary conditions (In, Out, Crossing)

d. Input values of zero, zero crossing, and approaching zero from either direction

e. Minimum and maximum input data rates in worst case configurations

f. Regression Testing for changes to SSCF software code

g. Operator interface/human errors during SSCF operations

h. Error Handling

i. Special features such as safety kernels upon which the protection of SSCF features is based

j. Formal Test coverage for software testing to include analysis and documentation

3.16.3.6 Software Reuse

a. Reused baseline software shall be evaluated to determine if it supports an SSCF in accordance with paragraph 3.16.1.

b. SSCF reused baseline software shall be analyzed for the following:

1. Correctness of new or existing system design assumptions and requirements

2. Changes in environmental or operational assumptions

3. Impact to existing hazards

4. Introduction of new hazards

5. Correctness of interfaces with system hardware, software and operator

c. Unused or unneeded functionality in SSCF reuse baseline software shall be eliminated.

d. SSCF reused baseline software changes in system design, environment, or operation assumptions shall be requalified or revalidated.

e. SSCF reuse baseline software compiled with a different compiler shall be analyzed and tested.

3.16.3.7 Commercial Off-the-Shelf Software

a. Each Commercial-Off-The Shelf (COTS) software application shall identify every SSCF supported.

b. Software Safety Hazard Analyses shall be performed on all SSCF COTS software to verify such software is sufficiently safe.

3.16.3.8 Language/Compilers

a. Production qualified higher order language compilers shall be used for SSCF code.

b. Beta test versions of higher order language compilers shall not be used for SSCF code.

c. The heritage of the language(s) and compiler(s) being used for SSCF code shall be clearly identified for each portion of the system design.

d. Translation routines/hardware between languages used in SSCFs shall be analyzed and tested.

e. Non-standard languages (those languages without production qualified compilers) used in SSCFs shall be analyzed and tested.

f. Programs or routines (compiled from different compiler versions) supporting SSCFs shall be analyzed and tested.

g. Programmable Logic Controllers (PLCs).

1. PLC use should be minimized in SSCF systems.

2. Where PLCs must be used in SSCF systems, the contractor shall obtain Range Safety approval and document the following in the Software Development Plan (SDP):

(a) The process to preclude hazardous or erroneous logic development

(b) The process to preclude erroneous logic entry into the PLC

(c) The validation process to ensure proper program operation. **NOTE:** If possible, this validation process should be accomplished in a non-hazardous state.

3.16.4 Computer System and Software Safety Data Requirements

The Range User shall provide the following SSCF related software information to Range Safety in the MSPSP or other documentation:

a. System description including hardware, software, and layout of operator console and displays

b. Flow charts or diagrams showing hardware data busses, hardware interfaces, software interfaces, data flow, and power systems

c. Logic diagrams, Software Design Descriptions (SDDs)

d. Operator user manuals and documentation

e. List and description of all SSCFs including interfaces

f. Software hazard analyses

g. Software Test Plan (STP), test procedures, and test results

h. SDP, including discussions on configuration control, COTS, and reuse

3.17 WR SEISMIC DESIGN

AFM 88-3, Chapter 13 places the WR in seismic zone 4. **NOTE:** Local geological structure determines zone determination 1 through 4 considering the potential severity, frequency, and damage of a seismic event. This designation means that the WR is located in the most severe seismic region. The probability of the WR being exposed to a great earthquake is large enough to require taking specific mitigating measures in design.

3.17.1 WR Seismic Design Standards

a. Seismic design of all new or modified equipment shall be in accordance with AFM 88-3, Chapter 13, and Sections A and B. Where specific design guidance is not provided in these manuals, industry standards such as SEAOC “Blue Book”, UBC, and ATC 3-06 shall be used.

b. Equipment that must remain operational after a seismic event shall be designed in accordance with an importance factor “I” of 1.5 per AFM 88-3, Chapter 13.

c. Equipment needed for post-earthquake recovery shall be designed to remain operational after a seismic event.

d. Where cost-effective, high-cost computer or electronic equipment should be mounted on seismic isolation bearings (SIB) to mitigate damage during an earthquake. FEMA 74 shall be used as a guide to reduce the risk of earthquake non-structural damage.

3.17.2 WR Design Criteria for Equipment That Can Cause Seismic Hazards

a. The Range User shall identify equipment that has the potential, directly or by propagation, to cause the following seismic hazards:

1. Severe personnel injury

2. A catastrophic event

3. Significant impact on space vehicle or missile processing and launch capability. **NOTE:** This criteria does not apply to commercial programs

4. Damage to high value flight hardware. **NOTE:** This criteria does not apply to commercial programs

b. For equipment that can present a seismic hazard, the Range User shall identify the expected “G” forces, the level of “G” forces the equipment can withstand, and the magnitude of potential damage.

c. For equipment that can present a seismic hazard, the following design criteria shall apply:

1. Equipment shall be restrained to restrict movement and withstand a seismic event, but need not remain operational after a seismic event.

2. Restraints shall be designed to withstand loads as described in the following paragraphs:

(a) Restraints shall be designed to react to accelerations equivalent to a horizontal force of two times the equipment weight, applied through its center of gravity, in the direction in which movement is restricted. As an option, instead of using a force of two times the equipment weight, calculations of force may be made in accordance with AFM 88-3, Chapter 13. Vertical accelerations shall be considered whenever appropriate.

(b) Restraints shall prevent tip over, collapse, excessive deflection, or sliding.

3. Equipment interfacing flight hardware, where the failure of the flight hardware may cause a seismic hazard, shall be designed to mitigate the seismic forces being transmitted to the flight hardware to the point that the flight hardware will not cause a seismic hazard

4. Equipment shall be located so as not to exceed facility design limits.

5. Equipment that is mounted on casters or wheels shall have provisions for locking these casters or wheels and shall also comply with applicable parts of this section.

6. The use of friction to resist seismic loads is permitted only when accompanied by proper load and risk analysis.

d. Items of equipment that present seismic hazards for a cumulative total of 24 hours or less during any 365 consecutive day cycle are exempt from the above requirements.

3.17.3 WR Seismic Design Data Requirements

a. The Range User shall identify equipment that has the potential, directly or by propagation, to cause the following seismic hazards:

1. Severe personnel injury

2. A catastrophic event

3. Significant impact on space vehicle or missile processing and launch capability. **NOTE:** This criteria does not apply to commercial programs.

4. Damage to high value flight hardware. **NOTE:** This criteria does not apply to commercial programs.

b. For equipment that can present a seismic hazard, the Range User shall identify the expected

"G" forces, the level of "G" forces the equipment can withstand, and the magnitude of potential damage and the method of restraint used.